Volume 10
Number 117 *The Iowa silo.*

Article 1

August 2017

The Iowa silo.

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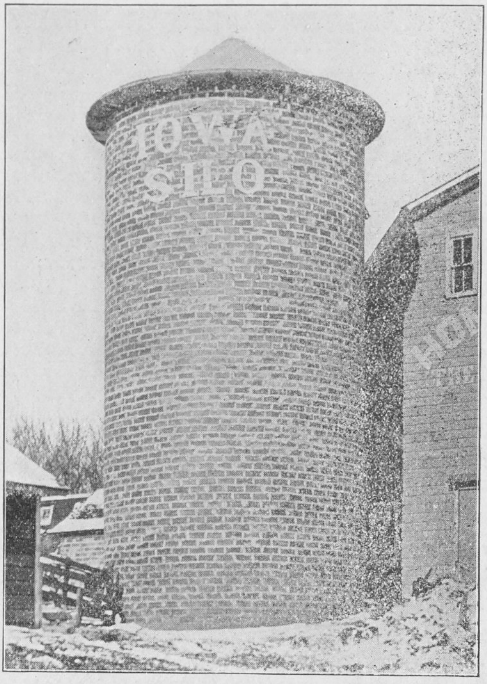
BULLETIN 117 JUNE, 1910

EXPERIMENT STATION

IOWA STATE COLLEGE
OF AGRICULTURE AND MECHANIC ARTS.

AGRICULTURAL ENGINEERING SECTION



IOWA SILO, ROCK VALLEY, IOWA

THE IOWA SILO

AMES, IOWA

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THE IOWA SILO.

J. B. DAVIDSON. M. L. KING.

INTRODUCTION

For several years the staff of the Agricultural Engineering Section of the Iowa Experiment Station has been making careful investigations concerning modern silo construction and the success and merits of each type now in use. The results of these investigations were first published in Bulletin 100, which was distributed in July, 1908. The demand for this bulletin was so large, not only from Iowa, but from other states, that a second edition was published in July, 1909. This bulletin treated of all the types of silo construction then in common use.

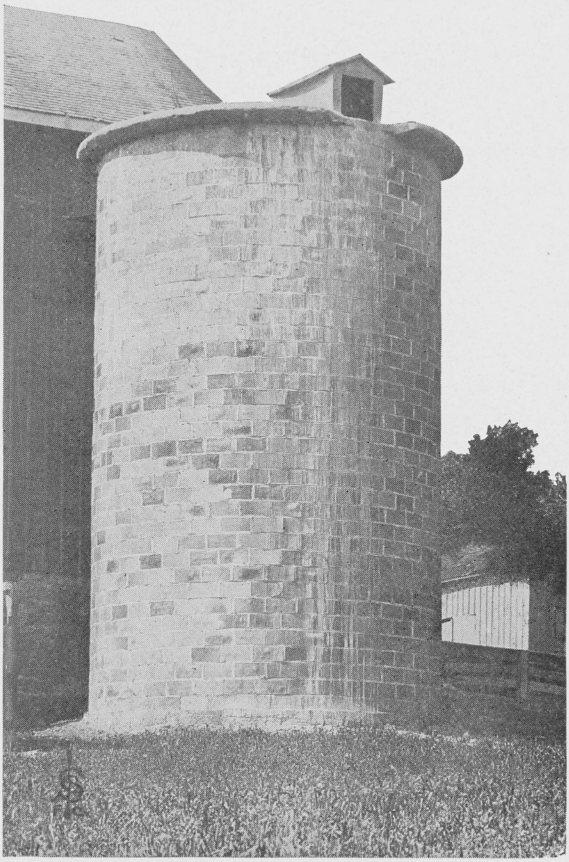


Fig 1. Iowa Silo No. 1, Ames, Iowa.

Bulletin 100, in addition to the data concerning the common types of silos, presented a design of a new silo, the walls of which were constructed of hollow clay building blocks. Because of being presented by the Iowa Experiment Station, it was called the Iowa silo. Although a silo after this design was under construction at the time of the publication of the bulletin, it was not possible to report in regard to its success in actual service.

At the time of the second edition, the experimental Iowa silo had been in actual service for one year and several other silos had been located with walls constructed of material much similar to that originally proposed for the Iowa silo. During 1909, several silos were built in different parts of the state. The uniform success of these silos, a detailed report of which will be given later, and the continued unshaken faith in the design, material and construction of the Iowa type of silo, lead to the publication

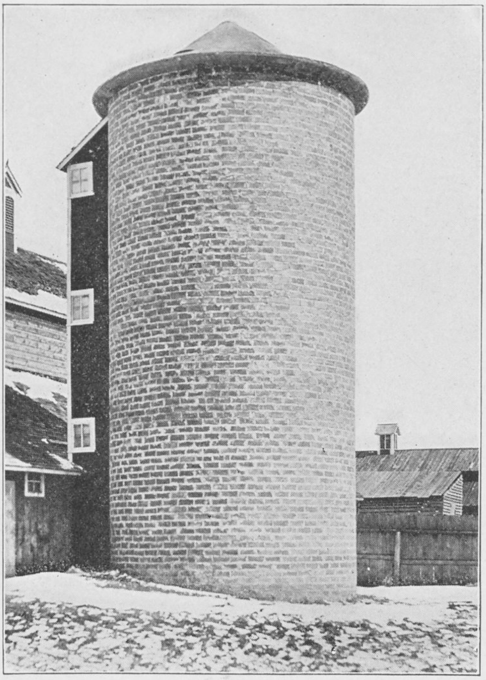


Fig. 2. Iowa Silo No. 4, Rock Valley, Iowa.

of a bulletin treating of the merits and construction of this one particular type. Since the publication of the two editions of Bulletin 100, there has been a large demand for information concerning the construction of the Iowa silo. It is the purpose of Bulletin 117 to furnish this in a detailed and illustrated manner which will enable any one desiring an Iowa silo either to construct it or to enter into a satisfactory contract with a mason or contractor for its construction.

In presenting this bulletin to the public, it is the wish of the authors that it be clearly understood that as members of the Agricultural Engineering Staff of the Iowa Agricultural Experiment Station, they do not favor or recommend any one type of silo above all others. Different types of silos have different characteristics or merits and upon individual circumstances and conditions will depend the type of silo which should be constructed. The selection of a silo consists in choosing the type whose characteristics are adapted to the conditions to be met.

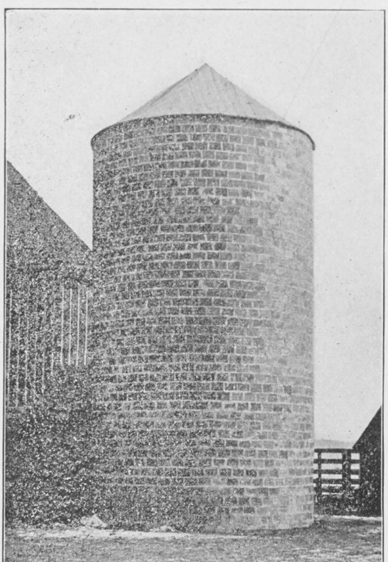


Fig. 3. Iowa Silo No. 6, Laurens, Iowa.

It is the duty of the Agricultural Engineering Staff to furnish definite information in regard to the success, durability and cost of all types of silos as far as possible, and their relation to the various conditions as they may exist.

Furthermore, it is the purpose of the authors to suggest improvements, and to design and develop new types of construction where direct benefit will come therefrom. In presenting in a detailed manner the Iowa silo, it is not intended that it should be recommended above all others. As reliable information as is possible to secure is furnished concerning its merits and faults and, no doubt, many desiring a silo will find the Iowa silo well adapted to their needs.*

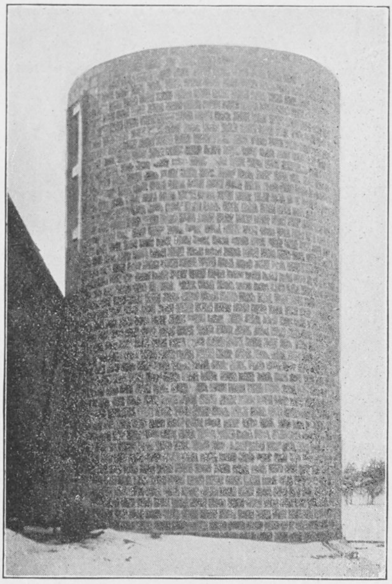


Fig. No. 4. Iowa Silo No. 8, Rockford, Iowa.

The use of hollow clay building blocks properly reinforced for silo construction was an idea which came to the junior author

*For general information concerning silo construction, the reader is referred to Bulletin 100, of this Station, "Modern Silo Construction." Information concerning concrete silo construction may be obtained from cement manufacturers or their associations. The construction of a stave silo is described in Circular 136, "How to Build a Stave Silo," Bureau of Animal Industry, U. S. Dept. of Agriculture. Silo manufacturers will be glad to furnish information concerning patented silos.

during the investigations of silo construction which were carried on previous to the publication of Bulletin 100. Since announcing the design, it has been learned that building blocks in more or less similar form, had previously been used in the construction of silos and the authors have not hesitated in any way to utilize the benefit to be derived from the experiences of others along this line. It is also desired to acknowledge the many valuable suggestions received from masons who have become interested in this type of construction, block manufacturers, members of the faculty of the Engineering Division of Iowa State College and others. Any suggestions whereby the present design may be improved will be gratefully received.

LIST OF IOWA SILOS

The following is a list of Iowa silos which have been built during the past two years. With the exception of the first, the experimental silo at Ames, all of these silos were constructed during the summer of 1909. Silos No. 11, 12, and 13, were constructed without the direct co-operation of the Agricultural Engineering Section. Views of several of these silos, numbered as in the following list, are to be found in this bulletin.

Number.	Location.	Diameter.	Height.
1	Ames, Iowa	16 ft.	30 ft.
2	Linn Grove, Iowa	16 ft.	35 ft.
3	Rock Valley, Iowa	16 ft.	35 ft.
4	Rock Valley, Iowa	16 ft.	37 ft.
5	Pocahontas, Iowa	18 ft.	36 ft.
6	Laurens, Iowa	18 ft.	36 ft.
7	Laurens, Iowa	16 ft.	30 ft.
8	Rockford, Iowa	18 ft.	35 ft.
9 and 10	Ottumwa, Iowa	18 ft.	35 ft.
11	Woodward, Iowa	16 ft.	32 ft.
12	Clarion, Iowa	16 ft.	36 ft.
13	Hawkeye, Iowa	12 ft.	36 ft.

ESSENTIALS OF A GOOD SILO

An attempt is here made to outline the essentials or points of merit to be found in the ideal silo. This is done in order that a direct comparison may be made between this ideal silo and the Iowa silo.

IMPERVIOUSNESS OF THE WALLS.

The fundamental principle involved in preservation of silage is the retention of moisture within the silage and the exclusion of air. For this reason, the silo wall must be non-porous. Moisture must be prevented from passing out and air from passing in.

RIGIDITY, STRENGTH AND SMOOTHNESS OF WALLS.

An ideal silo must have rigid walls. It must be strong enough to resist the bursting pressure of the silage. This acts outward in all directions as the silage settles. The friction of the silage against the wall, and the weight of the wall produce a crushing action which is great near the bottom of the silo. A silo when empty should be heavy enough to stand against heavy winds. The inside of a silo wall should be reasonably smooth to permit the silage to settle freely. If the wall is not smooth or if there are shoulders or offsets on the inside surface air pockets will be formed and a considerable loss of silage will result.

DURABILITY.

After due consideration to all other points of merit to be found in silos, the most desirable silo is the one that is the most durable and will give the longest term of service. The durability of a silo depends, first upon its strength, and second, the durability of the material used in its construction.

To be durable, any material must resist the action of the weather, the constant wetting and drying, freezing and thawing in the winter season, and any disintegrating action which may be due to the silage itself. Some material will disintegrate with age, and other materials suffer from rapid decay when subject to the warm, moist conditions which exist in the silo.

CARE AND REPAIR.

It is desirable that a silo require the minimum expenditure in the way of labor and material for its up-keep. A silo which must be adjusted for shrinkage and expansion is of less value than one which does not need such attention. Often this work is neglected, and loss results.

Some silos must be frequently repainted in order to present a pleasing appearance. This means added expense. All parts should be equally durable and lasting. The replacement of parts which are short-lived, the substitution of new pieces for those which have become decayed or faulty for any other reason, adds materially in many cases to the cost of maintaining the silo.

FROST RESISTANCE.

In Iowa the winters are so severe that it is difficult to construct a frost-proof silo. The silo wall which will prevent freezing to the greatest extent is the most desirable.

CONVENIENCE.

A silo should be convenient for filling and so arranged that the silage may be easily removed from day to day during the feeding season. The doors should be so constructed that they can be put in place and removed with the least effort. They should permit easy access to the silo and allow the removal of the silage with the least possible amount of labor.

PORTABILITY.

There are instances where tenants and others desire a silo which may be used in one place for a time and then moved to a new location. Under such circumstances, this feature should be given due consideration.

FIRE PROOF CONSTRUCTION.

It adds materially to the value of any building to be made of fire-proof material. The importance of this feature is realized when the large annual loss from fire is taken into consideration.

APPEARANCE.

All farm buildings should be of good appearance. This feature adds both to the attractiveness and the value of the farm. A permanent silo of neat appearance is the most desirable silo to construct, other things being equal.

SIMPLICITY OF CONSTRUCTION.

It is an advantage to select a silo which can either be constructed without special skilled labor, forms or tools, or can be purchased ready for erection without the aid of skilled labor.

COST.

One of the most important features to be considered in the selection of a silo is its first cost. The silo which will furnish storage for silage at the least cost per ton is the silo to build, other points being equal.

THE IOWA SILO

A discussion of the Iowa silo under each of the points of merit which have been mentioned follows:

IMPERVIOUSNESS OF THE WALLS.

Hard burned hollow clay building blocks will not absorb a large amount of water. Moisture is not readily transferred through a wall of such material. We recommend that only blocks which have a low absorption be used for silo construction. Blocks of this kind are more durable, and a silo built of them will preserve silage better.

The mortar used in laying the blocks should be a rich, water-tight mixture. This will resist the passage of moisture or air through the joints. To secure a more perfect wall, it is recommended that the inside be washed with cement. This will seal any minute openings or imperfections.

A careful personal inspection has been made of the silage in the thirteen Iowa silos which have been built up to the time of writing and, with one unimportant exception, the silage was found in first-class condition throughout the entire feeding season. There is no reason why the walls of the Iowa silo should not be entirely satisfactory for the preservation of silage. That they are satisfactory has been demonstrated by actual test.

RIGIDITY, STRENGTH AND SMOOTHNESS OF WALLS.

The outward or bursting pressure of silage has been found by previous experiment to amount to about 11 pounds per cubic foot. To be well designed, any silo must be constructed of material of sufficient strength to resist this pressure. Square silos are not well adapted to resist this bursting pressure on account of their flat sides. They are almost sure to bulge. For this reason the round silo is the most desirable form.

The silo, owing to its diameter and height, offers a rather large amount of surface upon which the force of the wind may act. For this reason the silo walls should be of rigid construction and not readily distorted or damaged by high winds. Furthermore, it is best that the structure should be heavy enough when empty to resist being moved readily from its foundation by strong winds. Some types are so light that they must be thoroughly tied to adjacent buildings and held to place by guy wires. The importance of this feature is emphasized through the fact that certain insurance companies do not care to insure such types of silos and either will not insure at all or only when extra charge is made for exposure. The Iowa silo is rigid enough and heavy enough so that it is not affected by wind.

Enough steel reinforcement is laid in the mortar joints of the Iowa silo to carry the entire bursting pressure of the silage with a reasonable factor of safety. Originally, the safe working load of the steel was taken at 20,000 pounds per square inch, which gives a factor of safety of three for steel rolled in relatively large bars. As it has been found that steel wire is the most desirable reinforcement, the safe working strength has been raised to 30,000 pounds per square inch. The drawing process through which wire must pass in its manufacturing increases its tensile strength and this change on the part of the designers is entirely justified as there is no reduction in the strength of the reinforcement. As originally designed, practically as much steel was included in the walls of the Iowa silo as was to be found in the hoops of the average stave silo which not only must resist the bursting pressure of the silage, but the swelling action of the staves. The form of reinforcement which has been found the most convenient for the Iowa silo is hard black, No. 3 steel wire which is laid in the mortar joints as described later.

Some silo walls have been known to crumple at the bottom, due to the weight of the walls themselves and to the friction of the silage. The 4-inch block wall of a 16 foot Iowa silo, 35 feet high, will carry not only its own weight at the bottom, but that of all the silage which could be placed in the silo several times ober.

When constructed of curved blocks, the Iowa silo has been made reasonably smooth on the inside, there has been no loss of silage from the roughness of the wall. Silo No. 1, which was constructed of 16-inch blocks with little curvature, permitted a few air pockets to form, resulting in a small amount of spoiled silage after being stored in the silo for two years.

DURABILITY.

The walls of the Iowa silo are constructed of hollow, vitrified clay building blocks which, as far as weather resistance is concerned, are as durable as any building material which can be obtained. Their durability corresponds with the durability of brick which is to be found in all parts of the state. This does not mean that all hollow building blocks are durable, for there are good and bad blocks on the market. Good blocks are so plentiful that no one need make the mistake of selecting blocks of questionable merit. A discussion of the quality of blocks is given later.

The roof of the Iowa silo, like the walls, is made of durable material. A cheaper roof may be used if desired, but it is strongly advised that the concrete roof be used where possible.

One common mistake met with in silo construction is that the door frame is made of material which will soon decay or rust and have to be replaced. The door frame of the Iowa silo is made of reinforced concrete which, when properly constructed, should be as durable as the walls themselves.

The materials used in the Iowa silo will resist decay, disintegration, the action of frost, and any implied or real action of the acidity of the silage. Even the steel which is placed in the mortar joints and concrete door frame as reinforcement, is thoroughly protected from rust. So carefully has the matter of durability been considered in the design of the Iowa silo that it would be difficult to estimate its life. When carefully built it ought to last for several generations.

The doors of the Iowa silo are designed to be made of wood. They will decay and must be replaced after several years. The convenience and low cost of the wooden doors, which may be easily replaced, justifies their use.

CARE AND REPAIR.

The Iowa silo when properly constructed is practically free from any expense for repair and maintenance. The only possible expense may be the occasional washing of the inside of the walls at intervals of not less than five years, with a cement wash and the replacement of the doors after they have become rotten from use.

FROST RESISTANCE.

Owing to the fact that all Iowa silos do not now have roofs and that no two men use the same methods in feeding silage, it has been difficult for the authors to compare the frost resistance of different types of silos. It is, however, a very conservative statement to say that the average amount of frozen silage found in the Iowa silos during personal inspection trips did not exceed the amount found in wooden silos in the same neighborhood and under the same conditions of exposure.

The hollow wall of the Iowa silo in which the circulation of air is quite thoroughly restricted, tends to make it frost resistant. Dry fir lumber is about six times as efficient a non-conductor of heat as vitrified clay. Since the Iowa silo wall is twice as thick as the average silo stave, and because it is only about one-fourth solid, it should be at least equally as efficient as a two-inch wooden wall which is always moist, a condition which lowers the efficiency of wood as a non-conductor. The

Iowa silo wall, however, is not nearly as frost proof as a double wall concrete silo or a cement block silo with less material joining the two walls and with restricted air circulation.

CONVENIENCE.

The Iowa silo has been designed and constructed with either individual or continuous doors. The continuous doorway has crossties 42 inches apart which is an important advantage over the usual construction which in some instances has hoops or ties as close as 26 inches. When crossties are close, the continuous door offers but little advantage if any over the individual door. With these improved doors, the Iowa silo offers as many advantages for convenience in removing silage as any construction now known. Fig 5 is a view of the continuous doorway of the Iowa silo, looking toward the roof, showing the large openings between the crossties.

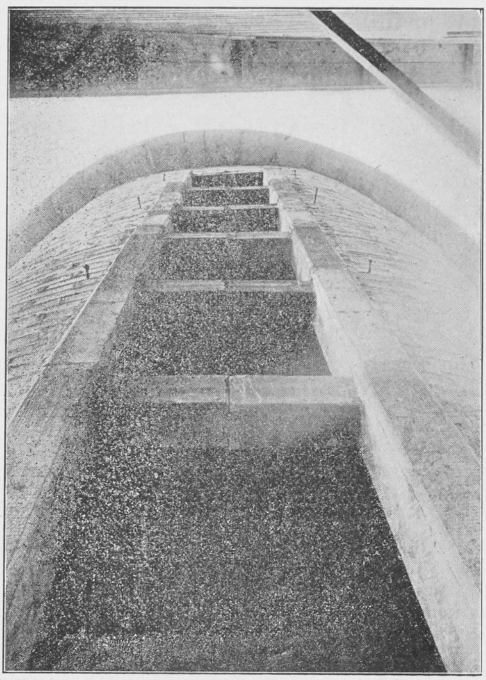


Fig. No. 5. View of Doorway, looking toward the roof. Notice the size of Openings.

The concrete roof of the Iowa silo has a wide, flat gutter in which it is possible to stand while adjusting the blower pipe of an ensilage cutter to the silo for filling. This is a valuable convenience compared with the usual steep roof upon which it is impossible to stand, requiring that the work of adjusting the blower pipe be done from the window or a ladder.

PORTABILITY.

In no sense can the Iowa silo be considered portable. If a silo is desired which must be moved to a new location after a few years, it is doubtful if the Iowa silo would fill the requirements. The roof and door frame would be entirely destroyed in moving and it would be worth nearly as much as the value of the blocks to clean them for use the second time.

FIRE PROOF QUALITIES.

The Iowa silo is perfectly fire-proof. It is hard to see how it could be even slightly damaged by a fire. In general, fireproof construction is given too little attention. One of the authors of this bulletin visited a masonry silo from which silage was fed within twenty-four hours after all the adjoining building had been burned from around it, leaving it unharmed and containing the only feed stuff saved from the fire. Hollow, vitrified clay building blocks are widely used for fireproofing purposes.

APPEARANCE.

The Iowa silo presents a pleasing appearance of solidity, durability and permanency.

SIMPLICITY OF CONSTRUCTION.

The concrete silo upon investigation has been found to be a satisfactory silo when carefully built. Its construction, however, is so difficult that very few really good silos have been found which have not been constructed by the professional silo builder. The manipulation and construction of the forms for building a concrete silo are so difficult that although a silo may be satisfactory as far as strength and keeping qualities are concerned, the walls are often rough, distorted and not of good appearance. Good forms for the concrete wall are expensive and considerable equipment is necessary to handle the concrete.

The walls of the Iowa silo are of a construction familiar to all masons and for this reason a satisfactory job is practically assured. The reinforcement of the walls with the steel laid in the mortar joints is a very simple matter.

The forms for making the reinforced concrete doorways, although of much the same character as those required for making a concrete silo wall, are much more easily handled and are quite simple. The scaffold for building the silo has been carefully worked out. The roof construction is simple and should not give anyone trouble who is familiar with concrete work in any form. The simplicity of the construction of the Iowa silo is indicated in Fig 6, which shows a wagon loaded with all of the scaffold, derrick, guide, mortar box, and tools used in construction of the 16x35 foot silo and roof shown at the left. A further idea of the simplicity and rapidity with which the Iowa silo can be constructed can be formed from Figs. 7, 8, 9 and 10, which show the daily progress of constructing a silo 18 feet in diameter with two masons and helpers at work.

COST.

An attempt has been made to determine accurately the cost of the original thirteen Iowa silos. A definite statement is hard to get, since in almost every instance the farm force assisted to a more or less extent, introducing items of labor, haulage, etc., difficult to estimate. The owners in most instances prefer not to take these items into account, yet in making a complete statement, they must be included.

Silo No. 1, owing to the fact that it was an experimental silo and that some of the material was secured at a cost below normal, is not listed here.

Silo No. 2 was built under normal conditions but certain experiments increased its cost to some extent over the next silo which was built. The development of certain features of construction, especially the scaffold, was a large factor in reducing the cost of those constructed later.

Following is a statement of the cost of Silo No. 2, which is located at Linn Grove, Iowa.

Fig. 6. Total equipment including Derrick, Scaffold, Guide, Mortar box, and

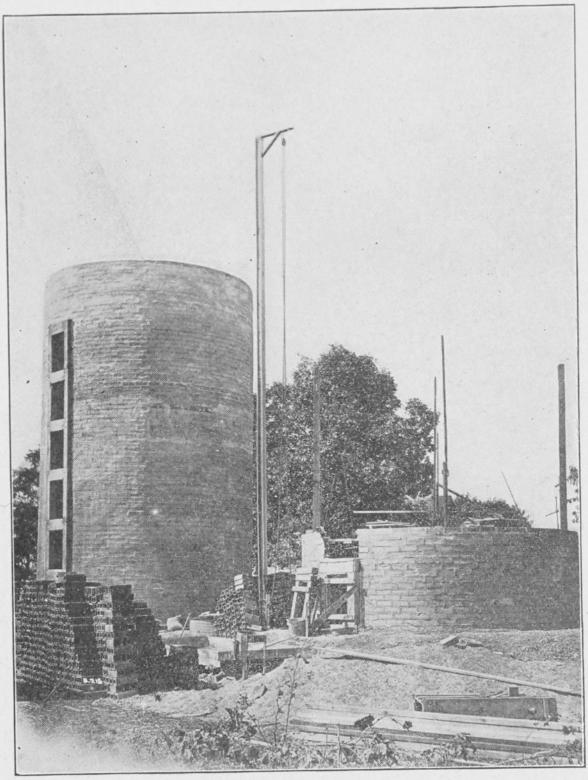


Fig. 7. Progress of construction. End of First Day.

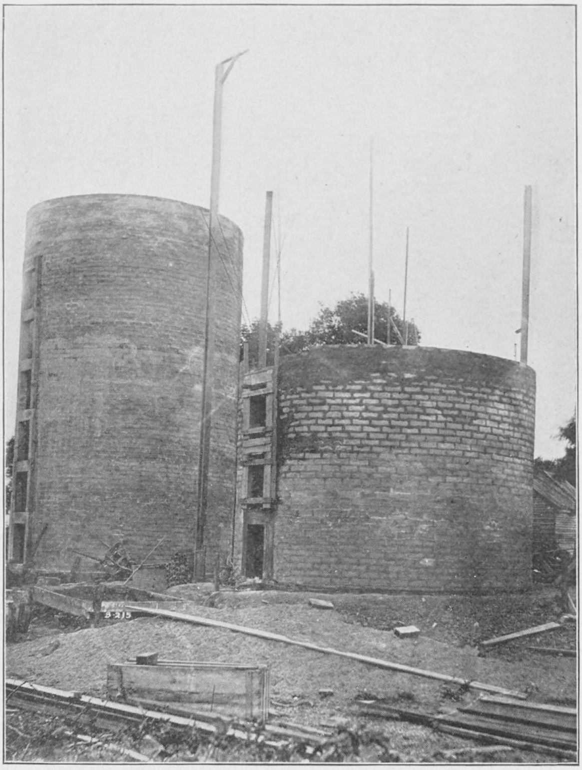


Fig. 8. Progress of Construction. End of Second Day.

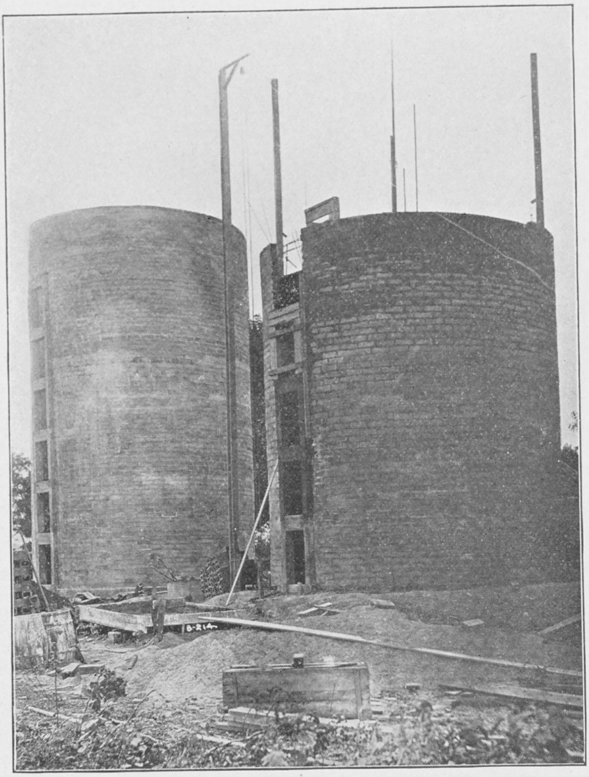


Fig. 9. Progress of Construction. End of Third Day.

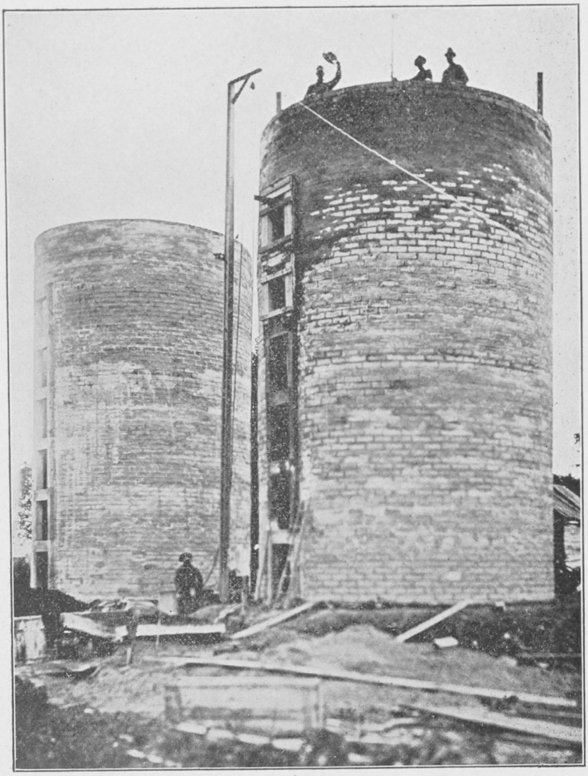


Fig. 10. Progress of Construction. End of Fourth Day.

REPORT OF THE COST OF IOWA SILO NO. 2, LINN GROVE, IOWA.

Size 16 feet in diameter by 35 feet high.

Excavation 3½ feet deep—		
Labor of superintendent, 15 hrs. @ 50c..........	$ 7.50	$ 7.50
Footing and Floor—		
Labor of superintendent, 9 hrs. @ 50c...........	4.50	
Labor of mason, 9½ hrs. @ 40c.................	3.80	
Labor of mason's helper, 9½ hrs. @ 30c..........	2.85	
56 ft. of discarded 36-inch woven wire fence......		
52 feet 4-inch drain tile.......................	1.68	
14 sacks cement @ 45c.........................	6.30	
4 yds. of gravel @ 25c.........................	1.00	20.13
Wall and Door Frame—		
Labor of superintendent, 65 1-3 hrs. @ 50c........	32.67	
Mason, 66¼ hrs. @ 40c.........................	26.50	
Helper, 66 hrs. @ 30c..........................	19.80	
Unskilled labor, 173 hrs. @ 15c................	25.95	
Blocks 4,000 4x5x12½ @ $17.50 per M...........	70.00	
Freight	19.42	
Cement, 38 sacks @ 45c........................	17.10	
Lime, 18 sacks @ 30c..........................	5.40	
400 lbs. No. 3 wire @ 3c.......................	12.00	
75 lbs. ⅜ steel, $1.31, cartage and freight 60c.....	1.91	
Sand, 4 yds. @ 50c............................	2.00	
Additional wire	3.87	236.62
Moving scaffold (old material used)—		
Labor of superintendent, 19 hrs. @ 50c...........	9.50	
Labor of mason, 16 hrs. @ 40c..................	6.40	
Labor of helper, 14 hrs @ 30c..................	4.20	
Labor of unskilled, 9 hrs. @ 15c...............	1.35	
Stirrups	7.50	28.95
Roof—		
Making cornice blocks—		
Labor of superintendent, 19 hrs. @ 50c...........	9.50	
Cement, 6 sacks @ 45c.........................	2.70	
Sand 2-3 yds. @ 50c...........................	.33	
10 lbs. No. 9 wire @ 3c........................	.30	
Setting cornice blocks—		
Labor of superintendent, 13 hrs. @ 50c..........	6.50	
Labor of mason, 13 hrs. @ 40c..................	5.20	
Labor of unskilled, 17 hrs. @ 15c...............	2.55	
1 sack of cement @ 45c........................	.45	
Wire for tying down...........................	.20	
Framing false work—		
Carpenter, 5 hrs. @ 30c........................	1.50	
Setting false work—		
Superintendent, 4 hrs. @ 50c..................	2.00	
Mason, 4 hrs. @ 40c...........................	1.60	
Helper, 4 hrs. @ 30c...........................	1.20	

Concrete—		
Cement, 18 sacks @ 45c	8.10	
Gravel, 3 cu. yrds. @ 25c	.75	
Placing expanded metal—		
Mason's helper, 13 hrs. @ 30c	3.90	
Expanded metal	15.80	
Freight	2.32	
Lumber of roof falsework, 124 ft. lumber @ $30 per M	3.72	
Labor of putting on concrete—		
Superintendent, 7 hrs. @ 50c	3.50	
Mason, 7 hrs. @ 40c	2.80	
Helper, 7 hrs. @ 30c	2.10	
Unskilled labor, 10 2-3 hrs. @ 15c	1.60	
Plastering roof and removing falsework—		
1-3 yd. sand @ 50c	.17	
3 sacks of cement @ 45c	1.35	
1½ sack lime @ 30c	.45	
Labor, mason, 10 hrs. @ 40c	4.00	
Labor, helper, 10 hrs. @ 30c	3.00	87.59
Lumber for door forms, 110 ft. @ $30 per M	3.30	
Labor of making, superintendent, 15 hrs. @ 50c	7.50	10.80
Lumber for doors, 150 ft. @ $35 per M	5.25	
Labor of making, carpenter, 3 hrs. @ 30c	.90	6.15
		$390.99

This statement is much larger than that furnished by the owner which is as follows:

Steel	$ 1.56
Freight	.35
Wire for eaves	.50
Molding	.15
Bolts	.40
Black wire	.50
Pipe	.15
No. 3 wire	12.00
Blacksmith	7.75
Common tile	1.68
Vitrified blocks and freight	89.42
Steel for roof	15.80
Freight for same	2.32
Telephone wire	3.87
80 sacks cement @ 45c per sack	36.00
6 loads of sand	1.50
5 loads gravel	1.25
2 2-3 bbls. lime	3.90
Labor	30.00
Mason work	92.00
Carpenter work	4.50
Boy labor	2.50
Total	$308.10

The latter statement represents accurately the actual cash outlay of the owner for the silo.

COST OF IOWA SILO NO. 3 AT ROCK VALLEY, IOWA.

Size, 16x35 feet, inside.

Excavation 3½ ft. deep—		
Labor of excavating and placing footing by contract	$ 10.00	
Cement, 2½ bbls. @ $1.60	4.00	
Gravel, 2 cu. yds. @ $2.00 delivered	4.00	$ 18.00
Wall and door frame—		
Labor of superintendent, 84 hrs. @ 50c	42.00	
Mason, 71 hrs. @ 40c	28.40	
Labor, 179 hrs. @ 20c	35.80	
Blocks, 4x5x12, 4,000 @ $17.50 per M	70.00	
Freight	20.88	
Hauling blocks	9.60	
Cement, 7 bbls. @ $1.60	11.20	
Lime, 3 bbls. @ $1.50	4.50	
Steel wire, 450 lbs. @ $2.37½	10.69	
Steel, ⅜-inch, 75 lbs., $1.31, cartage and freight 60c	1.91	
Sand, 4 yds. @ $2.25	9.00	243.98
Scaffold—		
Labor superintendent, 19 hrs. @ 50c	9.50	
Labor, unskilled, 16 hrs @ 25c	4.00	13.50
Material—		
5 pcs. 2x8x12.		
2 pcs. 2x10x16.		
4 pcs. 2x4x6.		
6 pcs. 2x12x14.		
8 pcs. 2x6x16.		
20 pcs. 1x6x16.—605 ft. @ 30c	18.15	
8 pins ¾x16 inches	.50	
4 wire stretchers @ 75c	3.00	
3 lbs. spikes, 16d	.10	35.25
Roof—		
Making cornice blocks—		
Labor of superintendent, 10 hrs. @ 50c	5.00	
Unskilled labor, 15 hrs. @ 25c	3.75	
Cement 5½ sacks @ 45c	2.48	
Sand 2-3 yds. @ $2.25	1.50	
Steel reinforcement 6 lbs. @ 3c	.18	
Setting blocks—		
Labor superintendent, 4 hrs. @ 50c	2.00	
Labor, mason, 4 hrs. @ 40c	1.60	
Unskilled labor, 12 hrs @ 25c	3.00	
1 sack cement	.45	
Wire for tying down	.30	
Framing false work—		
Carpenter, 4 hrs. @ 30c	1.20	

Setting—		
Superintendent, 2½ hrs. @ 50c	1.25	
Mason, 2½ hrs. @ 40c	1.00	
Carpenter, 2 hrs. @ 30c	.60	
Expanded metal, $16.00 and $4.86	20.86	
Placing expanded metal—		
Superintendent, 4 hrs. @ 50c	2.00	
Mason, 4 hrs. @ 40c	1.60	
Unskilled labor, 4 hrs. @ 25c	1.00	
Lumber for false work, 124 ft. lumber @ $30 per M.	3.72	
Cement, 20 sacks @ 45c	9.00	
Gravel, 2 yds @ $2.25	4.50	
Labor of putting on concrete—		
Superintendent, 8 hrs. @ 50c	4.00	
Mason, 8 hrs. @ 40c	3.20	
Unskilled labor, 21 hrs. @ 25c	5.25	
Removing false work and scaffold—		
Mason, 4 hrs. @ 40c	1.60	
Helper, 4 hrs. @ 30c	1.20	
Plastering—		
Mason, 5 hrs. @ 40c	2.00	
Helper, 5 hrs. @ 30c	1.50	
Cement, 3 sacks @ 45c	1.35	
Lime, 1½ sacks, @ 30c	.45	87.54
Lumber and bolts for door forms—		
Material—		
110 ft. @ $30.00	3.30	
12 bolts	1.00	
2 lb. nails, 7d	.06	4.36
Derrick—		
1 pc. 2x10x18.		
1 pc. 2x6x16.		
1 pc. 2x4x10.		
2 pcs. 1x6x16.—63 ft. @ 30c	1.80	1.80
Doors—		
Lumber, 272 ft. @ 35c	9.52	
Labor, 10 hrs. @ 30c	3.00	12.52
		$ 403.45

The owner of this silo states that, according to his accounts, this silo cost, without the chute, about $325 to $350.

REPORT OF THE COST OF OTHER IOWA SILOS.

The owner of Iowa silo No. 4 writes as follows:
"I hereby send you the figures for the cost of my Iowa silo.'"

Steel	$28.00
Brick	88.00
Cement	48.50
Lime	10.00
Labor, masons	62.50
Sand	10.00
My own labor	35.00
	$282.00

In regard to Iowa silo No. 6, the following statement was received: "Your letter of the 19th at hand and with pleasure will give an itemized statement not including your labor nor my own."

98 sacks of cement	$ 44.10
25 sacks of lime	6.25
7 yds. of sand	1.75
900 lbs. wire	27.00
2640 5x8x12 blocks	93.68
100 5x8x6 blocks	3.70
144 feet of ⅜-inch rods	3.00
5 doors	9.20
Mason work	96.00
Bolts for chute	.60
	$285.28

The cost of Iowa silo No. 7 was furnished by its owner in the following statement:

Labor	$ 65.00
Brick	74.00
Wire	18.00
Cement	30.00
Lime	5.00
Lumber	5.00
Steel rods and bolts	10.00
Four doors	8.00
	$215.00

The following is the cost of two Iowa silos, Nos. 9 and 10, each 18x36 feet, 30 feet above ground, 6 feet below, from the statement of the owner, which does not include price of roof.

Tile, 4x5x12 at $18.22 per M	$174.25
Wire for reinforcing	63 00
60 bbls. of cement @ $1.35	81.00
Brick masons @ 62½c per hr	124.23
Tenders at 35c per hr	60.35
Other help	31.10
Excavating	23.60
Lumber for forms and doors	23.75
Sand	45.00

Hauling tile	27.50
6 barrels lime	6.60
Work on foundation	23.24
Boarding of hands	33.60
Inc. including hardware, horse feed, R. R. fare, etc.	32.85
	$750.37

Silo No. 13 was built by contract for $381.60 complete with roof.

Attention is called to the fact that where experimental silos were constructed in co-operation with the Agricultural Engineering Section, no charge was made for superintendent of construction other than expenses, but his time has been included in the Section's estimate at 50 cents per hour.

The time of the superintendent devoted to each silo was as follows:

No. 2. Fifteen days.
No. 3. Fifteen days.
No. 4. Three days.
No. 5. Four days.
No. 6. Three days.
No. 7. One-fourth day.
No. 8. Seven days.
Nos. 9 and 10. Six days.

CONSTRUCTION OF THE IOWA SILO

THE LOCATION OF THE SILO.

A very large percentage of the silos used in Iowa are located outside of the barn. There are good reasons for this. First, the Iowa silo is of such a construction that it does not need the protection of a building. Second, it is not economical to place a silo in a building where it will occupy space which may be put to other use. Third, a silo located inside of a building is often unhandy to fill. The forage cannot be delivered to the cutter conveniently. Fourth, by locating a silo outside of the building and only connecting it thereto with a passage provided with doors, the objectionable odor of the silage may be kept out of the building. By arranging the silo so as to be connected to the feeding room with a feed way, it is as convenient for feeding as when located in the building itself. A very common arrangement is to so locate the silo that the passageway from silo to barn is a continuation of the feed way in the barn. In general, it seems that there are few advantages in building a silo inside of a building and many in building it outside. There are types of barns, the large round barn for instance, which are of a form making it possible for a silo to be conveniently located at the center.

FOUNDATION.

Any building should rest upon a foundation sufficiently broad to prevent appreciable settling, and deep enough to rest upon soil which is never disturbed by frost In the case of a masonry silo the foundation may be advantageously a continuation of the wall. If the space enclosed within the foundation be excavated, it becomes available for the storage of silage. This space, however, costs a little more than the space in other parts of the silo on account of the additional labor of excavation. Thus, it will be seen that it is not economical to extend the foundation deeper than necessary to get below frost. For the Iowa, a good depth of pit is three and one-half feet.

EXCAVATION.

After locating the center of the silo, the circle for the excavation may be laid out to good advantage by the device shown in Fig. 12. By using a carpenter's level on the sweep and a sliding block for making the circle on the surface, the difficulties encountered on sloping ground may be overcome. Some of the preliminary excavation may be accomplished by team and scraper.

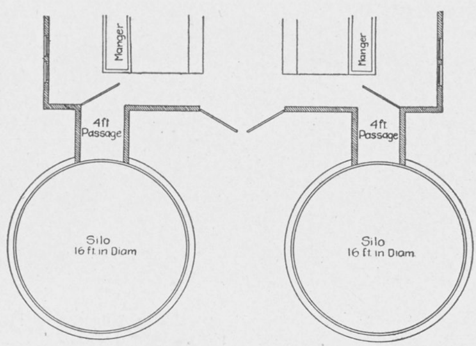


Fig. 11. Plan of Silos and End of Dairy Barn Showing a Convenient Arrangement.

DRAINAGE OF FOUNDATION.

In case there is a probability of ground water standing about the foundation, there should be a tile drain placed as shown in Fig. 13 and Plates I and V. Porous back filling placed outside the foundation insures that any surface or ground water will sink to the drain rather than fill the blocks of the wall through any crevice which may exist.

TYPES OF FOUNDATION.

There are at least four different types of foundations, one of which will be applicable to any conditions which may arise. The different types are as follows:

1. Building blocks throughout.
2. Concrete footing with blocks extending from the floor up.
3. Concrete footing with blocks laid on end and filled with concrete.
4. Concrete footing and foundation extending to about 1 foot above the grade line.

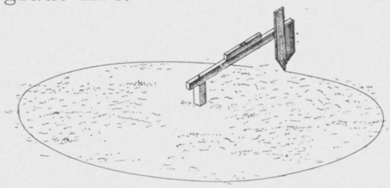


Fig. 12. Laying out the Circle for Excavation.

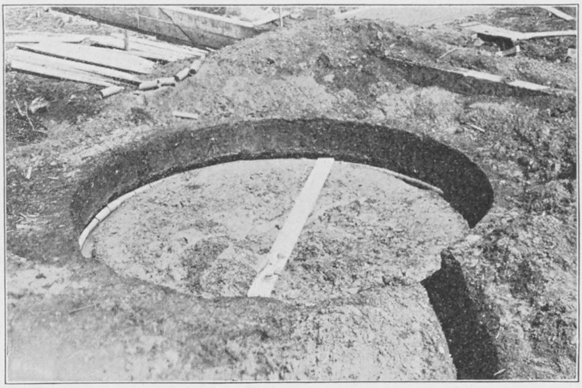


Figure 13. Excavation for Silo Showing Tile in Place for Draining Foundation.

No. 1 type of foundation is shown in Fig. 14. The first course of the footing is 16 inches wide, made of two eight-inch blocks laid flatwise side by side. Then the next course, 12 inches in width, should consist of blocks laid flat crosswise and bedded in mortar. This completes the footing and the third course becomes the first course of the wall.

The third and each succeeding course should be liberally mortared or plastered at the outside of the vertical joint. This reduces the liability of water getting into any course of the foundation. The lower course if connected to a drain would render any other drainage unnecessary.

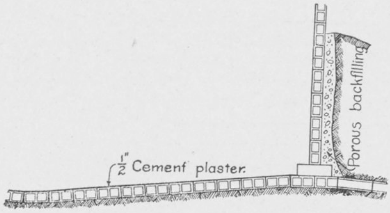


Fig. 14. Number One Type of Foundation. Constructed entirely of Building Blocks.

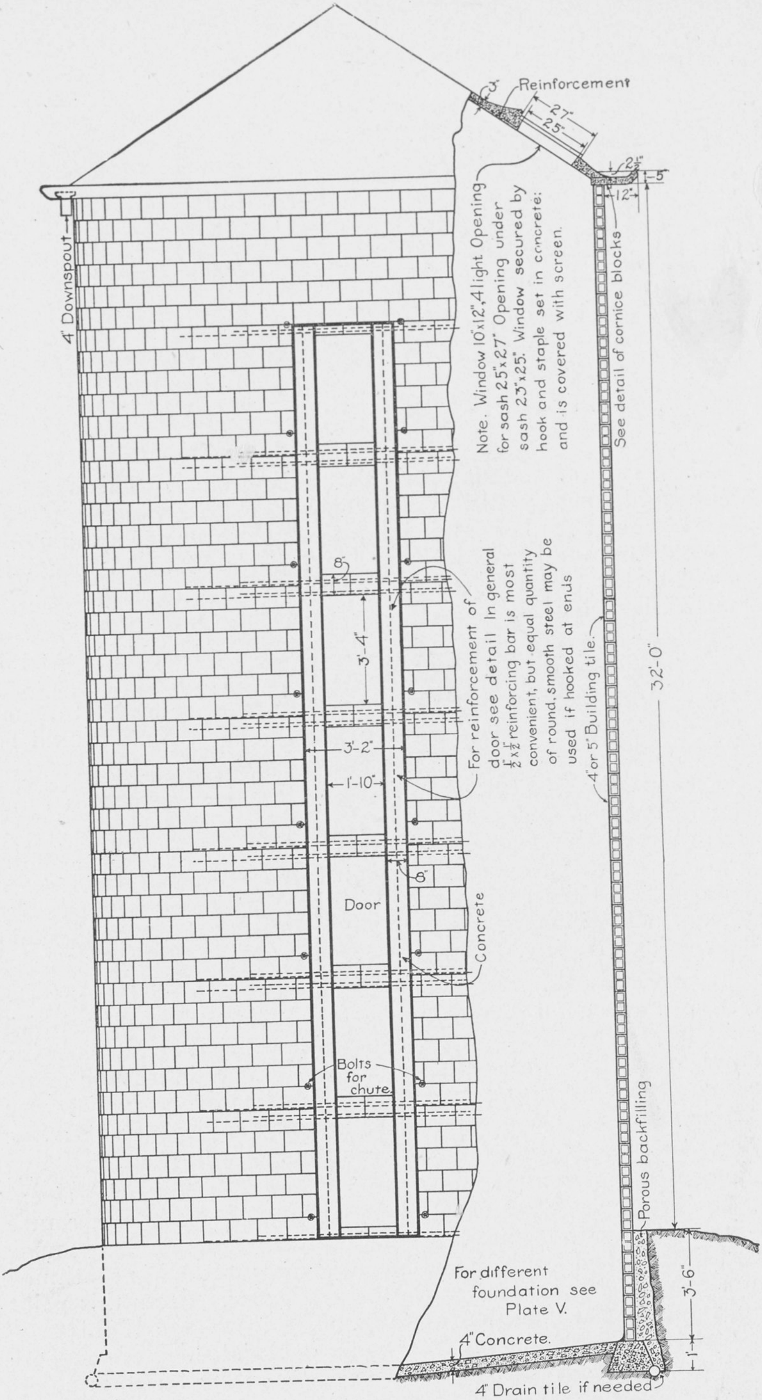
No. 2 type of foundation is shown in Plate I. This form of foundation simply consists of a concrete footing which is placed in a trench at the bottom of the pit, 12 inches or one spade deep, 8 inches or one spade wide at the top, flared to 16 inches in width at the bottom. On the top of this footing is placed the wall built of blocks.

These two types of foundation are often advisable because a form is not required for building them. Choice between Nos. 1 and 2 would depend entirely upon their relative cost. In communities where sand and gravel are expensive, No. 1 would be cheaper.

Perhaps the greatest objection that can be foreseen to these two forms of foundation is the possibility of the blocks of the wall filling with water, which through carelessness or faulty drainage might be standing against the wall. In case water stands against the wall, it would in time seep through the faulty mortar joints into the air space of the wall, where it might do damage by freezing.

In order to prevent any such trouble, the outer joints may be left open at a point directly under the roof down spout, at which point there should of course be special provisions for carrying away all surface water which may collect. This may be easily accomplished by filling over an opening in the drain tile with coarse material, which will always permit the passage of surface water directly and quickly to the drain.

No. 3 type of foundation shown in Plate V is built with a concrete footing upon which blocks are placed on end, each course being filled with concrete as it is placed and another course placed and filled in a similar manner. This method is continued to a point at least a foot above the grade line. From this point up, the blocks are laid horizontally. The advantage of this type is that the possible danger from water is obviated. More expense and work is incurred, although no material for forms is necessary.



ELEVATION AND SECTION
IOWA SILO

PLATE 1.

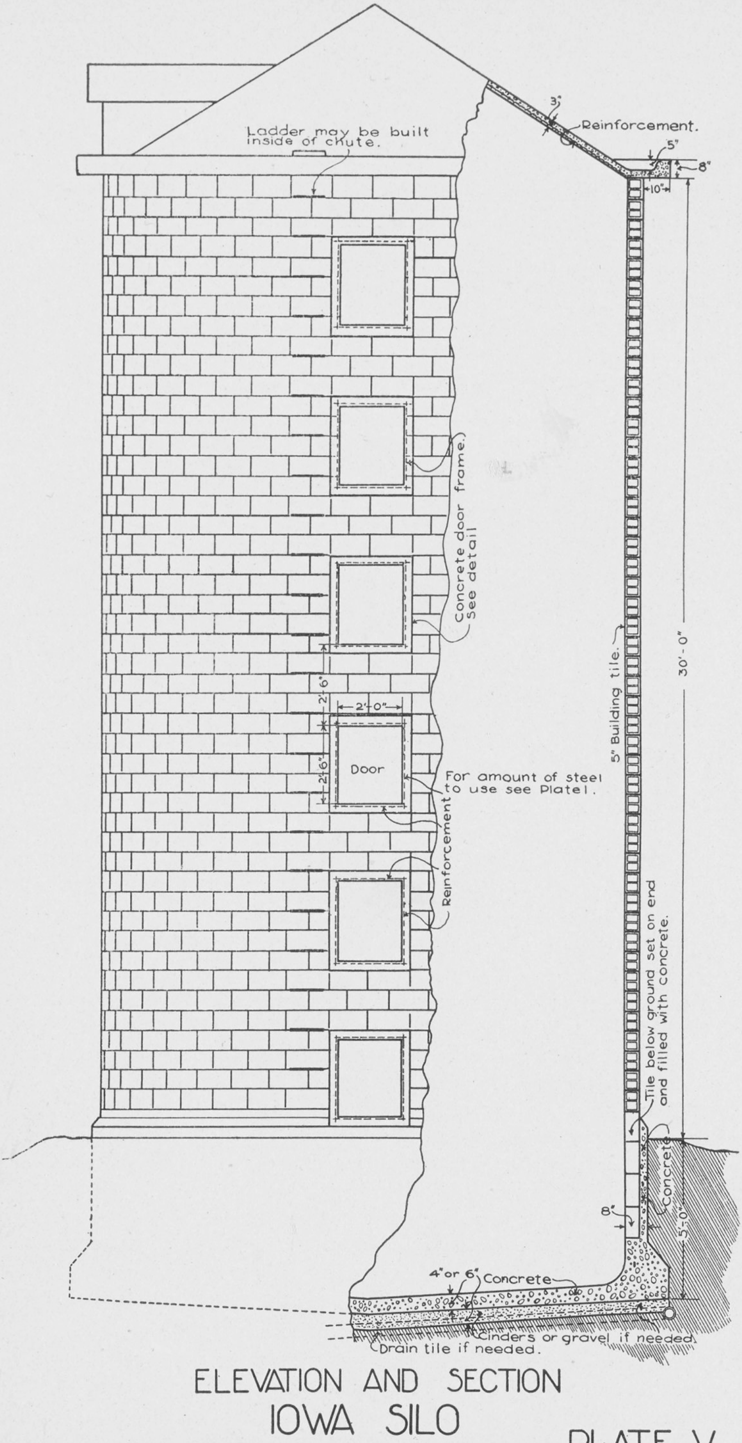
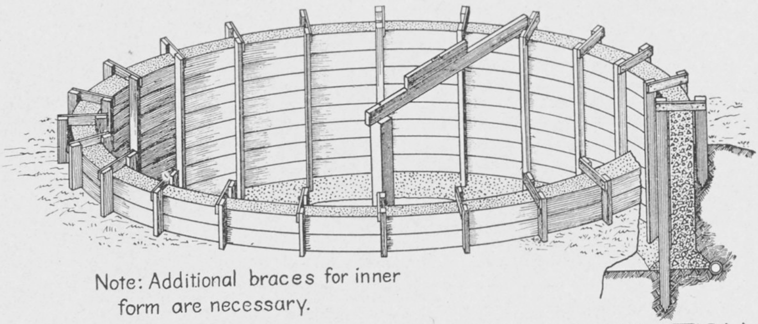


Plate V. Elevation and Section of the Iowa Silo Individual Doors.

No. 4 type of foundation is shown in Fig. 15. Earth is utilized for the outer form but lumber is used for the inner. By permitting this to extend down only to within a few inches of the bottom of the pit, the footing may be permitted to widen. This is desirable as a wall need never be as thick as the width of the footing. In case the ground is reasonably level and firm, it will be cheaper to simply dig a narrow trench and widen same at bottom to 16 inches. If ground is excavated next day and concrete trimmed, a reasonably smooth job is insured.



FORMS FOR MAKING CONCRETE FOUNDATION

Figure 15. Number Four Type of Foundation.

THE FLOOR.

Under certain conditions, the silo floor may be dispensed with without interfering with the preservation of the silage. Where the silo rests upon dry clay or any nonporous soil, and where the foundation is deep enough to prevent undermining by rats, the floor may be omitted. Usually, however, a floor is desirable. The portion of the silo below the ground may be made more nearly water tight, the floor may be thoroughly cleaned, and there is no mixing of earth with the silage. A silo floor need not be thick or expensive, as the weight of the silage, though very great, is evenly distributed over the surface and would be just as firmly supported if the floor was not used. A concrete floor of the usual sidewalk construction, three to four inches in thickness, will be very satisfactory. If properly graded sand and gravel can be obtained, one part of cement to five parts of sand and gravel will be about the right proportion to use. The concrete should be thoroughly tamped and troweled.

In some cases where sand and gravel are expensive, it may be cheaper to use a clay sidewalk block or even a hollow block, the same as used in the wall, covered with thin coat of plaster. In the case of the sidewalk blocks, the plaster covering would be unnecessary if the blocks were laid in cement. The floor should be slightly hollowed in the center as a matter of economy and convenience.

THE SILO WALL.

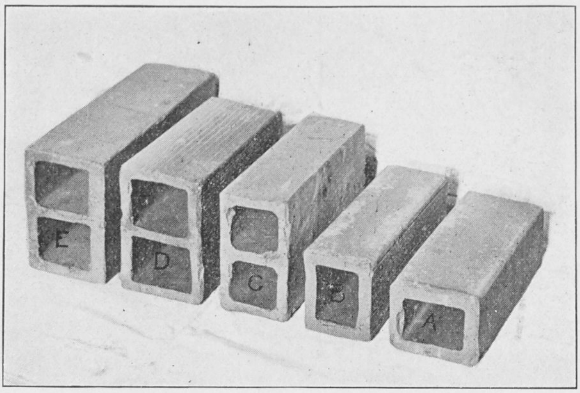
The first consideration in the wall is the selection of the material. The material used in the Iowa silo as originally designed was rectangular, hollow, clay building blocks, such as have been commonly used extensively in important buildings for years. It was originally designed with a plaster coat of cement mortar both inside and outside. However, the experimental silo shown in Fig. 1 was not plastered either inside or out but simply washed on the inside with a cement wash and, for the time it has been in use, it has been entirely satisfactory, indicating that the plastering is not necessary where a tile block is used which will resist the weather. In fact, only two of the silos in the bulletin have been plastered. It is to be noted that the durability of this silo will depend directly upon the quality of the blocks. Soft blocks which have not been properly burned should be guarded against. On the other hand, good vitrified blocks are among the most reliable and durable of all building materials.

It would be difficult to overestimate the advantages of curved blocks. The only spoiled silage found near the walls of silo No. 1 was a slight amount not exceeding one to four cubic feet or .01 to .06 of one per cent of the total amount. This spoiled silage was found in the recesses of the wall, which was quite rough due to the use of long, 16-inch straight blocks. A workman lays up the curved block more rapidly, and with more satisfaction than the straight block. The wall is smoother inside and out which is of obvious advantage to the preservation of silage inside and the appearance outside.*

Five different sizes of blocks have been used in building these silos. The different sizes are shown in Fig. 16. The first two on the right are of the same size but show two different positions in which they have been used. They are each 4x5x12 inch blocks. If laid as shown at A, they form a 5-inch wall, and each increases the height of the wall four inches, but if laid as shown at B they form a 4-inch wall, each increasing the height of the wall by five inches. C, the next size shown, is a 4x8x12 inch

*The curving of these blocks is not so difficult that any manufacturer should hesitate in doing it. The authors make no pretense of being clay-workers, but have personally helped to arrange a cutting table to bend these blocks automatically. An outlay of a few dollars is sufficient to equip an ordinary cutting table for this bending. Then no other extra labor is necessary as the ends need not be cut radial and they will fit concave to convex sides, thus little difficulty will be found in setting them in the kiln.

block which, for ordinary silo work, has proven itself more desirable than any of the other sizes used as it forms a 4-inch wall which is abundantly strong for the purpose and each block forms an 8-inch portion of the wall. With this block less mortar is required than with any other size block because it is the largest of the 4-inch blocks commonly manufactured within the state. Thus the mortar joints are fewer than in any of the smaller blocks, while they are fully as far apart and narrower than in the case with any of the larger blocks. Also it forms a warmer wall than the smaller size blocks as there is less material extending across the wall to conduct heat away from the warm silage. It is also easier for the mason to handle as he can grip it in one hand conveniently, while a larger block is tiresome to handle. Also in turning a circle with a thicker block, the outer joint stands open proportionately farther. In addition to this, it has the advantage of being more easily bent than a larger block, and costs less as such material is sold by volume.



E D C B A

Fig. 16. Five sizes of Hollow Vitrified Clay Building Blocks which have been used in Silo Construction.

The next size block shown, D, is a 5x8x12 inch block. Several silos have been built of this size block and perhaps in some it has offered a slight advantage in that the thicker wall will offer a proportionately greater resistance to the escape of heat from the silage. However, it is more expensive and difficult to handle than the material for 4-inch walls. The block shown at E is a 5x8x16 inch block. For general work, this size has several disadvantages. In the first place, few manufacturers make it, therefore, it cannot be considered a standard material. Also it is heavy to handle and must be bent considerably more than a short block in order to lay smoothly in a wall of the same radius. The outer joints are more open and, if not bent, the wall is objectionably rough.

The mortar used for this work is composed of cement, lime, and sand. The sand should be medium fine. A certain amount of lime is necessary as cement mortar is not plastic enough to stick to the ends of the blocks when applied. No more lime should be used than necessary to make the mortar workable. The quantity of lime for this purpose will vary somewhat with the material and workman. Perhaps the least amount of lime which could be made to serve the purpose, is one part of cement, 1-3 of one part of lime, and two parts of sand, while one part of cement, one part of lime, and four parts of sand is as much lime as would ever be required and at the same time provides a mortar of good quality. The hydrated lime generally sold in paper sacks is a very convenient form of lime to use as it can be mixed dry with the cement and sand. Enough may be mixed dry to last one-half day, then wet down as it is needed. The importance of measuring all materials and thoroughly mixing them cannot be emphasized too strongly. Thorough mixing is absolutely essential for a smooth mortar. Very few men can make a uniform quality of mortar without measuring the materials.

In order that cement mortar may set properly, it must contain considerable water. If this water is drawn out by coming in contact with hot, dry blocks, the mortar cannot harden properly. A hard block will of course absorb less moisture than a soft one but both hard and soft blocks, if warm, should be dipped for a few moments just before laying.

The most convenient and advantageous place for the reinforcement in this type of a silo is in the mortar joints. The size of steel necessary is less than the thickness of the mortar joint; therefore, it does not interfere with the laying of the blocks and, by placing it in the mortar joint, it is thoroughly protected from rust. The amount of steel necessary is shown in Plate II, and the size of wire most suitable will vary with the size of the silo and its availability. Heavy wires are not generally carried in stock, therefore, a decision in regard to the size to be used should be made and the order placed at least a month before building. It is hoped that the demand will cause manufacturers to carry a sufficient supply to be able promptly to furnish silo builders with material. The size of the wire most convenient to use is No. 3, which is ¼ inch in diameter. This is as large as can be handled in the mortar joints conveniently, but it is not larger than necessary. Even with this size of wire it is necessary in

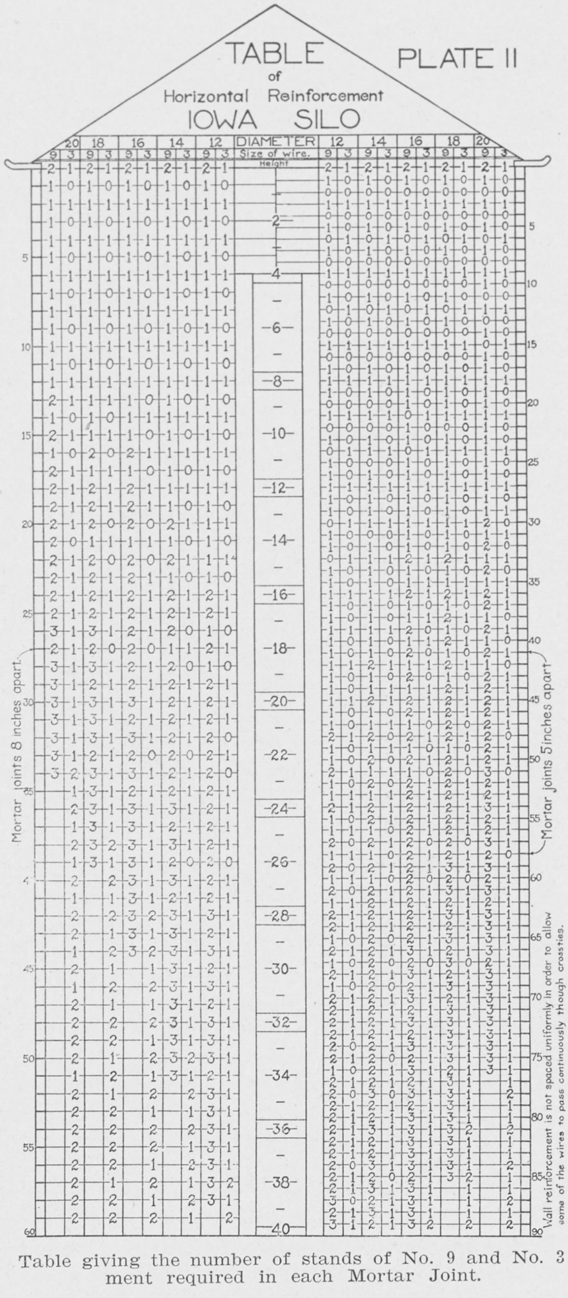


Plate II. Table giving the number of stands of No. 9 and No. 3 Reinforcement required in each Mortar Joint.

the case of large silos, and 8-inch blocks, to place more than one wire in each mortar joint near the bottom. However, if convenient to purchase, it will sometimes be advantageous to purchase No. 6, 8 or 9 wire for the upper portion of the silo where less reinforcement is necessary. The wire, when embedded in the mortar, will not rust, therefore, black wire should be used as it is cheaper than galvanized. All wire should be stored in the dry where it will not rust. The most desirable quality is hard or high carbon wire. Soft or medium wire is difficult to straighten and kinks badly in handling, thus causing considerable trouble. Hard or high carbon wire is as cheap as any, more convenient, and stronger. These heavy wires are wound in coils, therefore it becomes a very important problem to straighten them sufficiently to lay on the wall.

In Plate II is shown the number of wires No. 9 or No. 3, which should be placed in each mortar joint of any silo varying in diameter from 12 to 20 feet and 40 feet or less in height, with mortar joints 5 and 8 inches apart. The left half of the plate is for mortar joints placed 8 inches apart while the right half is for joints 5 inches apart. Most standard material is such as to be laid in one of these two ways. The top row of figures on either side of the plate indicates diameters. The left figure of the double column below each large figure indicates the number of No. 9 wires while the right of the double column indicates the number of No. 3 wires for each joint. The preceding wire sizes or numbers refer to the American Steel & Wire Co. gauge. The distance from top of silo should be the basis of calculation at all times.

In practice, the table would be used as follows: For example, take a 16x36 silo made of 4x8x12 blocks, reinforced with No. 3 wire. In the left half of the table under 16 at a depth of 36 feet is found mortar joint No. 54 which should contain two No. 3 wires. Succeeding joints should be reinforced as indicated in this column successively above.

The most convenient method tried for straightening this wire which is shown in Fig. 17 may be described as follows: Secure or build a reel from which a coil of wire may be conveniently unwound. Mount this reel upon a plank or platform where it will turn easily, then secure a short piece of gas pipe close to the reel as shown in Fig. 18.

Through this pipe draw the wire as it uncoils from the reel. The pipe should be so placed that its curvature will be the reverse of the curvature of the wire in the coil. At a convenient distance from the pipe, drive a stake, at which point the wires

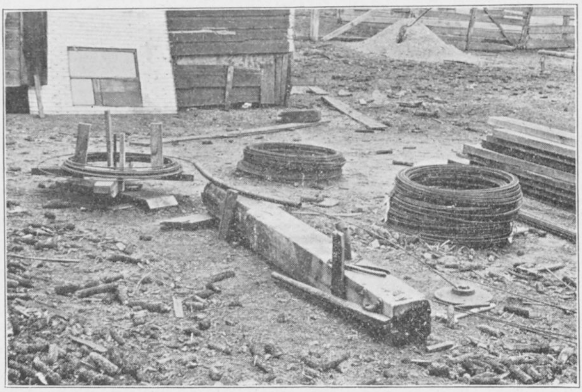


Fig. 17. Showing method of straightening wire by drawing through bent pipe.

may be cut to their proper length. In order to determine this length easily, another stake may be driven to which the end of the wire may be pulled each time before cutting. As soon as the first wire is cut, it should be laid upon the wall or fitted to a similar sized circle to see if the curvature is correct. If not, the curvature of the pipe may be altered and, by a few trials, the proper curvature secured.

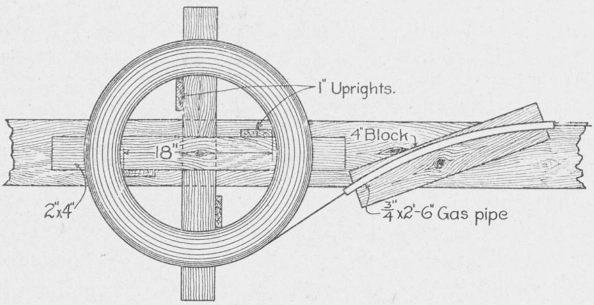


Fig. 18. Reel and Device for Straightening Wire Reinforcement

The horizontal or bed joints should be thoroughly bedded to cover the steel reinforcement. The vertical joints at the block ends should be made with extreme care in order to insure per-

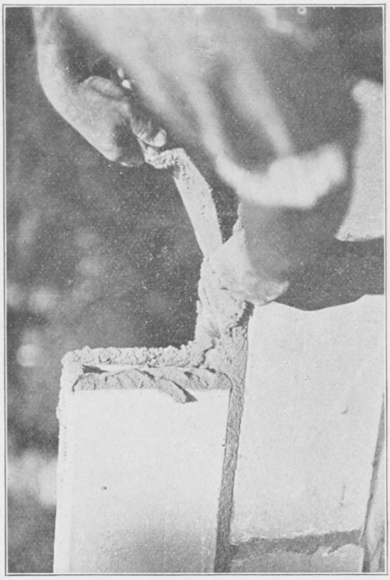


Fig. 19. Proper method of making Vertical Joint in wall.

fect air and water tight joints. In order to do this the ends of both blocks should be mortared before pressing together. A well mortared block end is shown in Fig. 19.

The outside joints should, for the sake of appearance, be struck neatly with the trowel as the work progresses, and for warmth they should of course all be tight. On the inside, however, this is scarcely sufficient as there might still be an occasional opening left between the ends of the blocks, which would permit the air to enter. In order to close all such openings, the mortar may be left hanging on the inside or cut roughly, then while still green washed with a cement wash before the scaffold is raised or the work left for the night. This wash naturally brings to view any crevices which may exist. These may then be filled with mortar, and this thoroughly seals the inside of the wall. This wash is composed of cement and water mixed to about the consistency of good paint and can be applied with a broom. The wash should be applied vigorously in order to smooth down and fill the irregularities. This operation in shown in Fig. 20.

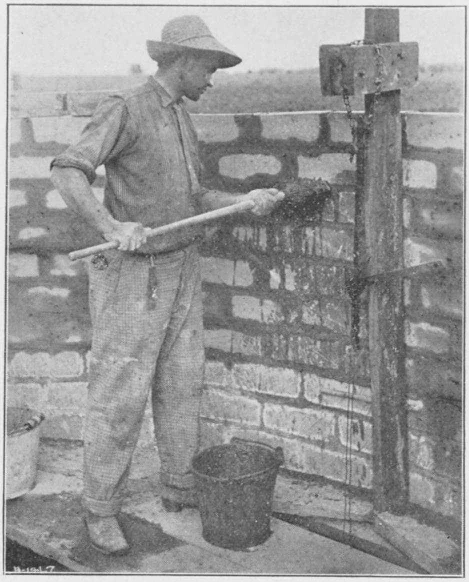


Fig. 20. Finishing the inside with a Cement Wash.

QUALITY OF MATERIAL.

In clay blocks there are many grades of quality ranging from almost worthlessness to one of the highest quality of building material known. These variations in quality are due mainly to three causes, quality of raw material, method of burning, and defects in forming.

Brick clays are made up principally of two classes of material, one that melts at temperatures usually secured in the hottest portions of the brick kilns, and one that remains firm at these same temperatures. Proper portions of each of these classes of material are essential. The former called the fluxing material melts and binds together particles of the latter, while the latter preserves the desired form of the brick or block throughout the burning process. It will be readily seen that as the fluxing material fuses it will fill all of the space between the other particles, and upon extreme heating it flows out over the surface giving it a glassy appearance. This process is known as vitrification.

In the manufacture of the blocks, on account of their being made up entirely with thin walls, it is necessary to use a clay which is comparatively low in fluxing material in order that the blocks will hold their shape well during the burning. Thus it will be seen that completely vitrified blocks are not usually made, but good semi-vitrified blocks are sufficiently dense to be extremely durable and are usually well shaped.

In order to appear hard burned and to present a glassy surface to the weather, clay products are sometimes treated externally with salt which, when burned, causes the block to have a glassy surface. It is evident that such treatment, though protecting the block to a certain extent, affects only the surface. The advantage of such a surface, however, is not sufficient to compensate for its interference with the detection of soft or porous blocks.

In some clays are found pebbles of lime-stone. These pebbles, after burning, absorb moisture, slake, swell, and chip particles off the block. This defect is serious and blocks extensively affected in this way should not be used.

In forcing some clays through the die the parts separated by the auger do not properly unite again. The result is stratified or grained appearance of the fractured end of a block which should show dense uniform material.

Frequently otherwise good blocks have a slight check in one of the outer walls. If this occurs at either end, a small amount of mortar may be placed inside of the block covering the check. However, if such a check is large enough to materially weaken the block, it should be discarded.

In all kilns the blocks nearest the fire become burned harder than the other blocks and in any kiln only a portion of the blocks will be fit for silo construction. For this reason silo builders should not expect to secure such blocks at less than standard prices plus a reasonable price for sorting.

The greatest danger from inferior material is the liability to disintegrate due to the action of frost while wet. It will be readily seen that this action only affects porous blocks as no appreciable amount of water gets into the dense blocks. However, in case the openings in a porous block are filled with water and exposed to freezing temperatures, the material surrounding the pores will crack open by the expansion of the water by freezing. Some clays appear to have a greater elasticity or toughness, therefore, are able, even though porous, to withstand this action somewhat more successfully than others.

The most general and reliable test which can ordinarily be applied to this material is a determination of the percentage of moisture that a block will absorb. Such a test is quite easily made and in case the quality of material is questionable, the purchaser of these blocks may well afford to use this test.

The method of procedure is as follows: In order to remove all of the moisture present in a block and have standard conditions from which to start, a block should be thoroughly dried. This is accomplished by placing the block in an oven or a similar place where the temperature will be above the boiling point of water for forty-eight consecutive hours. The block should then be carefully weighed and covered with water for forty-eight hours. Upon removing the block from the water, it should be wiped dry and again carefully weighed. If the difference between the wet and dry weights amounts to 8 or 10 per cent of the weight of the block when dry, the quality is very likely to be too low for use in silo construction.

This test gives excellent indications of the comparative qualities of blocks made from the same clay, but is not reliable as a method of comparing blocks made from different clays. Therefore with safety and in justice to all, it seems to be best to advise that in case the absorption should amount to 8 or 10 per cent, consultation should be had with a reliable engineer. The Agricultural Engineering Section will either test or have tested any samples of blocks sent for the purpose, at the cost of the work.

When investigating the quality of a certain building block, it is sometimes possible to find brick and blocks made by the same machinery and of the same clay as the material in question, which have been in foundations or side-walks for a term of years. Where such conditions do exist, the most positive evidence of quality are attainable as it is then only necessary to make sure that the material being purchased is burned as hard or harder than the material found in use.

Only unquestionably good blocks should be put in the ground or near the grade line. All questionable blocks, if used at all, should be put in the top few feet of the structure. The medium quality should be used for the main wall. A quality of block which would be entirely satisfactory for portions of the wall above the foundation might not be permissible for foundation work on account of the moisture present on the outside near the grade line. However, it must be remembered that it is always best to get unquestionable material for the whole silo even though the cost of the material or freight be considerably more.

LAYING THE WALL.

The following method may be only one of several practical methods, but it has been followed successfully several times.

The first course should be spaced around 1-8 to 3-16 of an inch apart without mortar in order to determine the proper diameter of silo and length of guide. This will overcome the necessity of cutting blocks. Steel should be placed upon the outer half of courses in order that there shall be enough mortar inside to bear against the wire and hold the blocks. Loose blocks may be placed temporarily upon the wall to hold the steel in place at intervals of 6 or 8 feet as occasion requires. Steel upon the courses below and above the doorways should be long enough to lap past each other and be hooked as shown in Fig. 21.

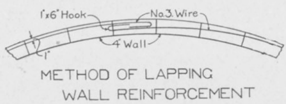


Fig. 21. Method of lapping Wall Reinforcement.

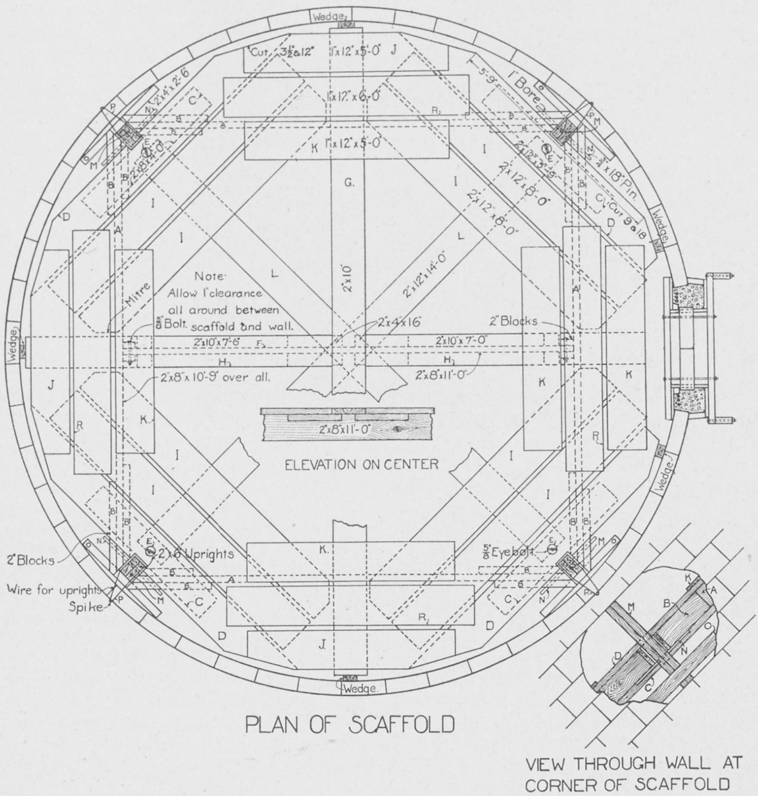


Fig. 22.

It is difficult to over-estimate the advantage of convenient, safe, and simple scaffold for any masonry construction. Three distinct types of scaffolds were tried and the one shown in the bulletin was found to be superior to any other type tried or known by the authors.

This scaffold is shown and all parts lettered for sake of a clear description in Figures 22 and 23. The drawing shows the top side of the scaffold, while the photgraph was taken from the floor beneath.

This scaffold differs from most building scaffolds in that the platform is movable. The platform itself consists essentially of a square frame work of 2x8's of reasonably clear, stiff lumber. These are shown by the dotted lines at "A," also in the corner elevation. Their length for a 16 foot silo is approximately 10 feet 9 inches. At the ends of

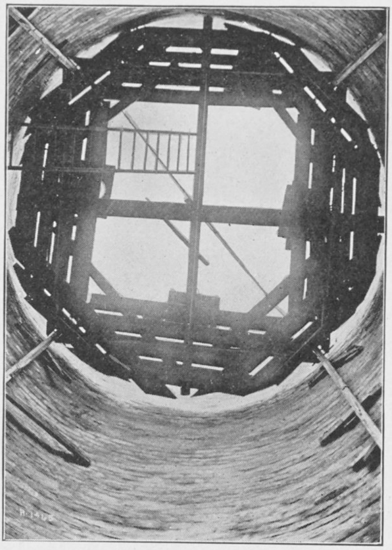


Fig. 23. View of Scaffold from center of Silo Floor.

these and flush with the bottom of each are securely nailed 2-inch pieces, "B," of convenient length. Thus the bevel at the end extends through three 2-inch pieces instead of one, and furnishes ample bearing upon the supporting pins, "N." There should be at least ¼-inch of clearance all around the post, "M." This frame work is held together at the corners by an eye bolt and a 2x8x4 beneath shown by dotted lines at "C" and the outer foot plank above. The eye bolts, "E" which secure these corners should be made of ⅝-inch metal with washer at each end. The length should be from 11 to 12 inches between the washers. Diameter of eye should be 1 inch inside and four are required. A 2x8, 11 feet long shown at "F," bolted at each end to blocks which in turn nailed to the middle of the two opposite members "A." Upon this frame work is placed a 2x10, 15 feet 10 inches long, indicated by "G" lying flat across the center of "F," and the two members "A."

Extending at right angles from "G," and lengthwise upon "F" are two timbers, 2x10, 7 feet, 6 inches long, indicated by "H." Beneath and nailed to the inner end of these timbers "H" are blocks which extend two inches under "G." By placing these blocks on each side of "F," it is not necessary to nail "H" to "F." It is highly desirable in a scaffold which must be used repeatedly that no nails need be drawn when knocking it down. Wood soon becomes so broken and split that it will not hold nails. Upon the corners of and diagonally to this frame are laid, inside of "D," two widths of plank 2x12, 8 feet long, lettered "I," and, conecting the ends of these and resting upon the ends of "G" and "H," are three boards 1x12, 5 feet long, lettered "J," beveled at the corners to fit the circle, also five boards 1x12, 5 feet long, lettered "K," which are not beveled. The four boards 1x12, 6 feet long, lettered "R" complete the upper part of the platform. Beneath the platform, for reasons seen later, are suspended by several strands of No. 9 wire, two 2x12, 14 feet long, lettered "L." These should be about 4 feet below the top of the platform. The wire hangers should be at the ends and in the middle. If strong 1-inch hard lumber is at hand, it may be substituted for the 2-inch upper foot planks shown in drawing. In fact this plan may often be changed to suit materials at hand, but in case all new materials are to be bought, the plan shown will be found to give general satisfaction and all parts having been used repeatedly are known to be sufficiently strong. Four upright posts lettered "M," secured to the wall at points approximately equally spaced, support the scaffold platform by means of ¾-inch round steel pins 16 inches long, "N," extending through 1 inch holes in the uprights. Eight of these are required, as one set should not be removed from a lower hole until the other pins are placed to support the scaffold in case any of the hoisting device should break.

Each upright consists at first of 2x6, 8 feet long and 2x6, 16 feet long, screwed together with three 2½-inch No. 14 or No. 16 flatheaded wood screws. It is necessary to use the flatheaded screws in order that the head will countersink itself into the wood, thus not interfering with the raising of the scaffold platform. One of the bottom members of the upright is 8 feet long and the other is 16 feet long in order that the post may be added to as needed by simply screwing 16 foot length, 2x6 on alternate sides. These upright posts are secured to the wall by means of light wires lettered "P" which are placed about 3 feet apart vertically. Every alternate time the scaffold is moved two-inch blocks lettered "O" should be placed snugly between the post and the wall and nailed to the wall. This places the post about three inches from the wall. Then it should be toe-nailed to the blocks, and the wires passing through the wall drawn tight. This holds the scaffold support rigid in all directions and enables the builder to keep them plumb. It is better to block two of these upright posts each time the scaffold is raised rather than to block them all each alternate time. The distance between the holes in the upright will depend upon the kind of hoisting apparatus used. In the past wire stretchers have been used for this purpose. One type of lever wire stretcher was attached to a clevis secured to each post at a convenient distance above the platform and an eye bolt in the corner of the platform. A detail of this clevis is shown in Fig. 24. By the use of these stretchers, it was possible to raise only one foot at a time. Therefore the holes were necessarily one foot apart and three raises were made consecutively, thus the masons found it necessary to build only three feet of wall from each position of the scaffold which was a great convenience and permitted more rapid and better work.

The common double pulley block wire stretcher has been used very successfully. It has several advantages over other kinds. With the ordinary length of rope, the platform may be lifted 18 inches each time, thus accomplishing a three foot lift by only two changes or with longer rope, the three foot lift can be accomplished at one pull. An advantage in the hoisting may be obtained by standing upon the wall instead of upon the scaffold, thus reducing the weight to be lifted, very materially. A bit of plank lying upon the wall behind the post is convenient to stand upon. Anyone preparing to build several silos could well afford to invest in hoisting apparatus consisting of triple blocks and half-inch ropes. In any kind of hoisting apparatus, light castings, crimped chains, and unwelded eyes should be carefully avoided.

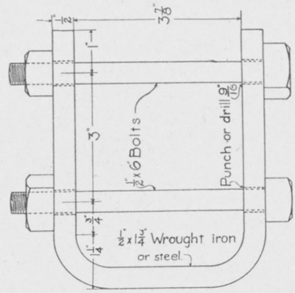


Fig. 24. Clevis for attaching Scaffold Hoisting Device to Posts.

In laying any straight masonry wall, a line may be used as a guide for securing a proper shaped wall. In the case of a circular wall this is manifestly impossible. Here the need of some sort of a guide is even greater than is the case with a straight wall as the eye of a mechanic cannot be trusted to determine a curve as he would a straight line. In the silo it is essentially important, for the sake of appearance, preservation of the silage, and strength of the wall, that it shall be circular and plumb. It is highly desirable that a guide shall be simple, easily used, and in the way as little as possible when not in use. It is of course possible to build a wall circular by starting the circle then using the plumb at intervals on the wall, however, the guide devised has been found better for this purpose by men who have tried both ways. It is also advantageous since, by means of it, the owner of the silo may in a very few moments detect any faulty shape of wall. It is merely necessary to determine the proper position of the scaffold by means of the plumb-bob, then follow the end of guide around wall. All blocks should be within less than half or three-fourths of one inch of guide and even these variations should be gradual so as not to form shoulders in wall.

The device is shown in drawing Fig. 25. A piece of ¾ or 1-inch straight gas pipe indicated by "A," 7 or 8 feet long may be secured as a center about whch to revolve a light arm, "B." The outer extremity of this arm, "C" is hinged in order that it may not interfere with walking around the scaffold. Also when not in use "C" may be placed in the position shown in the figure. It is not necessary to use the guide for each block, but is very convenient for determining whether or not the blocks are properly placed, and after laying six or more blocks, their position may be checked by means of this guide before the mortar joints are pointed.

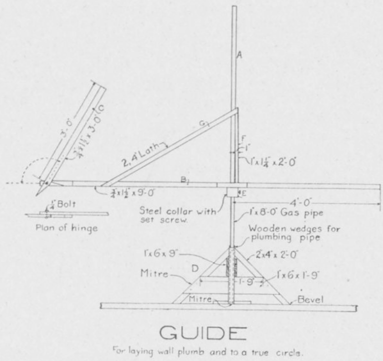


Fig. 25. Guide for laying wall plumb and to a true circle.

The extension of the main part of the arm "B" beyond the gas pipe is for convenience in case two masons are working on the wall. When not in use the portion of the arm should be left in the position shown in the drawing. Then the mason on the opposite side of the wall from where the guide has been used, may give the other extremity of the arm a push which causes it to revolve. The stand lettered "D" is made of 2x4's or any convenient lumber by means of which the gas pipe may be held in a vertical position upon the center of the scaffold. Then collar and setscrew lettered "E," are used to raise the revolving arm to a level with the top of the course being laid. The upright lettered "F" and two laths lettered "G" serve the evident purpose of holding "B" in a horizontal position. It will be readily seen that the guide at once becomes useful not only in securing a circular wall but in making the course level, as the end of the arm, of course, revolves in a horizontal plane. This device has proven itself to be very convenient. In order that the piece "A" may be in the center of the silo, after each raising of the scaffold, it is only necessary to suspend a plumb-bob from a point under the center of the scaffold to a nail in a stake in the bottom of the silo. With this as an indication of the proper location of the scaffold, the latter may be forced to place by dropping wedges between the scaffold and the wall, as shown in Fig. 21.

Two general methods have been followed in hoisting material on to the scaffold. In building the first silo, a 2x6 was projected out over the wall, supported from the scaffold by other light timbers 6 feet high. A pulley was secured to the outer end of the 2x6 projecting over the wall and the material was

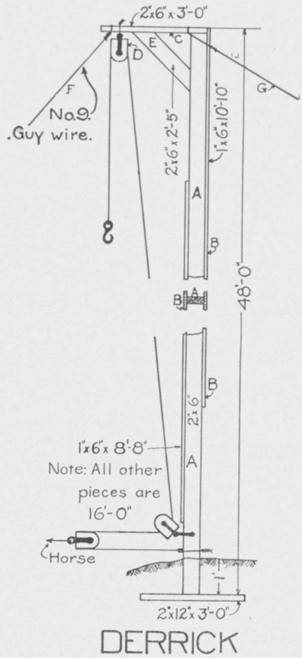


Fig. 26.

hoisted by a horse in this manner. This method was found to interfere with the use of the guide of Fig. 25, therefore a derrick after the plan of Fig. 26 was used.

This derrick, 48 feet high, is built of three pieces, 2x6, 16 feet long, lettered "A," and six pieces, 1x6, 16 feet long, lettered "B," besides the pieces necessary for the arm at the top. As seen in the cross sectional view in the center, the 1x6 is nailed flatwise upon the edges of the 2x6, thus forming an I beam. All the members are so placed that no joints are closer than five feet and four inches. The 1x6 on the back side of the upper 2x6 extends up flush with the top of the 2x6, "C," thus the 1x6 may be nailed to the 2x6, "C," and will prevent the back end from raising, due to the weight of the load on the pulley, lettered "D."

A short 2x6 strut, lettered "E," supports the other end of the 2x6, lettered "C." Two number nine guy wires, lettered "F," are secured to the outer end of "C" and fastened to stakes driven into the ground considerable distance away from the bottom of the derrick. These prevent any side motion of the arm where the pulley is attached, while a third guy wire is fastened to the top of the upright and extending away from the silo secures the derrick in the other direction. This derrick has been thoroughly tried out with loads up to 400 lbs. With the usual loads raised which are less than 100 lbs., it should be entirely safe. The derrick should be constructed on the ground and raised after the guy wires, pulley and rope have been attached.

In case a building is close, the upper end of derrick may be lifted from the top of the building and then pulled out to a vertical position by a rope or the guy wires. In case a building is not convenient it can be pushed part of the way by means of pike poles and pulled the rest of the way by rope or the guy wires. It is an advantage to hitch the horse to a snatch block, thus lessening his travel and increasing the speed of the load. By building the derrick to a height of 48 feet there is sufficient clearance between the top of the derrick and the roof of the silo to permit any material to be easily landed even on the roof.

DOORS.

In the Iowa silo two types of doorways have been used. One may be called an individual doorway, while the other is similar to what is generally known as a continuous doorway but the crossties are much farther apart. Each of these door frames is made of thoroughly reinforced concrete and is designed to be as strong as any part of the silo wall.

The individual doorway is shown in Plate V. The size of the openings made has been 32 inches in width, by 34 or 36 inches in height. This would of course vary somewhat with the size of the block. Then three or four courses of blocks are placed between the doors. This spaces the doors 30 or 38 inches apart. The dimensions given are most convenient for 8-inch blocks but by slight variation any size of blocks may be used.

Ordinarily the silage is pitched out of an upper door until the surface is worked down to about the middle of the next door below and then by digging a little away from the next door it may be opened. It will be seen that this plan necessitates the pitching of silage to a maximum height of about four feet.

The continuous doorway shown in the Plate I, is 22 inches in width and 40 to 48 inches in height, with only 8 inches of masonry and steel between the doorways. This makes a very convenient size of opening as compared to the 20x26 or 30 inches ordinarily found in silos. It will be found convenient to make the doors in sections about 2 feet in height. Any definite height is not important as the crossties between the doors are out far enough to clear the doors themselves which do not need to join the crosstie in this way. Thus it will be seen that it will never be necessary in the case of the continuous doorway to pitch the silage over 18 inches high.

Each of these types of doorways have been found sufficiently strong and easily sealed, therefore as the continuous doorway has been found to be more convenient, it is in general more desirable. Also after building several of each, it is the opinion of the authors that the continuous door is somewhat cheaper and is more convenient to build on account of the fact that the forms rest directly upon each other and fasten together in a more simple manner than is the case with the individual door.

The individual door frame as shown in Fig. 27 consists of reinforced concrete on all four sides of the openings and, as already discussed, a few feet of wall between door frames.

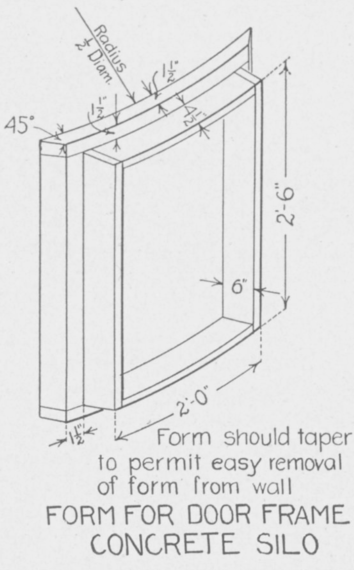


Fig. 27. Form for Individual Concrete Door Frame.

The form used in building this type of door-frames consists of two sets, one of which is shown in the Fig. 28. The set shown consists of the inner part, "A," and an outer part, "B." For the first doorway of a silo, "B" is secured in a vertical position by stakes and braces. A few inches of the bottom portion lapped past the upper course of blocks. Then the steel rods are bent in a square of sufficient size to be placed in the center of the concrete frame.

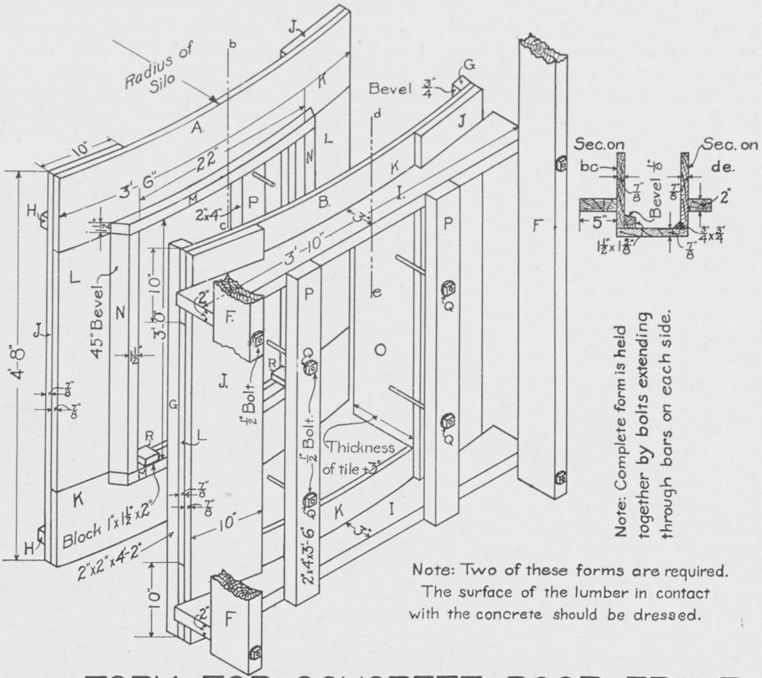
The strength of this steel should be such that the portion at the top and bottom should be equivalent to 50 per cent more than the strength of steel in the wall which is interrupted by the doorway. Thus it will be seen that the doorway does not occasion a weakness in the wall. Then course after course of blocks are laid around the silo, each course projecting past the edge of the form an inch or two. This continues until the top of the form has been reached. The horizontal steel from the wall should hook into the vertical steel in the door frame.

As soon as the wall is completed to the top of the door form, the inner part is bolted to the outer and moderately stiff concrete is poured into the form until it is full. This must be thoroughly tamped in order to insure the filling of all of the corners of the form, but the concrete should not be excessively wet, nor should it be tamped more than necessary on account of forcing so much concrete into the block wall. In tamping heavy bars should not be used. It is only necessary to use a convenient stick by means of which the concrete is thoroughly vibrated in order that all voids among the reinforcing rods and in the corners of the forms shall be filled. When the form is filled with concrete to a point level with the upper course of blocks, the next course may be continued across the door frame. The two door forms should be provided in every case and the second one may be bolted to the first by means of 2x6's as shown broken at "F." These should be made long enough to extend past both forms. In this way the forms may be used alternately and each day's work may be equal to the height of two doors, as the forms are ready to move after one day.

In case of a 4 or 5 inch wall there is scarcely room to conveniently place the necessary amount of steel and concrete in this door frame, therefore it has been found best to put strips, lettered "G" around the two sides and bottom of the outer form which will bear against the wall. This strip should be of sufficient thickness to make the door frame at least 7 inches from the inside to the outside. These forms are somewhat more expensive to make than the forms for the continuous door frames as it is necessary to make them curved. However, several of them have been made at a cost for labor and material not to exceed twelve to fifteen dollars.

For the sake of those not accustomed to working from drawings, it seems advisable to give more definite directions for the construction of these forms. Each piece will be referred to by letter, and the dimensions of the same are shown in the drawings. The order of procedure outlined is not the only one that may be followed. All lumber that comes in contact with concrete should be dressed. The pieces lettered "H" and "I" will be approximately 3 inches wide at the center. These sticks are not curved enough to prevent the use of a common hand saw in making them. Each of these four members must be notched at the center in order that the four pieces lettered "J" may extend from the top to the bottom of the form and still permit the members lettered "K" to extend full width of the form and bear directly against members "H" and "I." The members "K" must be bent to the same curvature as "H" and "I." In order to bend these it will usually be necessary to run saw kerfs more than half way through the board from the inner side of the curve. Between the members "K" on either side of both inner and outer forms are nailed boards lettered "L."

The strips lettered "M" and "N" extending around the opening of the inner part of the form should be made 1½ inch thick with a 1½ inch face as shown, and beveled between 1 and 1½ inches so that any swelling of the doors will not cause them to stick. Only a slight bevel of the members "M" at the top and bottom are necessary as the boards of the door are vertical and do not shrink and swell in that direction. Three boards, only one of which can be seen at "O," are nailed to the outer form and extend over to the inner, setting snugly inside of the strips "M" and "N." No such a board is required at the bottom of the form as this would cause difficulty in filling the lower part of the form with concrete. This leaves the lower part of "N" liable to be crowded in by the concrete, therefore it is necessary to nail the blocks, lettered "R," to the inner form. Four 2x4's, "B," only three of which can be seen, are nailed to the forms for the purpose of passing bolts lettered "Q" through, to draw the forms together. In order that one pair of forms may be held in place by the other without bracing to the scaffold or any other building it is convenient to use the 2x6's, lettered "F," by means of which the two outer forms are secured to each other.



FORM FOR CONCRETE DOOR FRAME
IOWA SILO

Fig. 28.

CONSTRUCTION OF CONTINUOUS DOORWAY.

The continuous doorway as shown in Plate I, consists essentially of a continuous door jam on each side of the opening. These jams are made up of reinforced concrete. The horizontal reinforcements of the silo wall hook into the vertical reinforcements of the jam. The jams are tied together at intervals of

4 or 5 feet by steel within the crosstie blocks. This steel not only extends into the vertical jam, but in order to be more secure, extends several feet into the wall on either side of the jam.

These crossties may be built, as shown in Figures 5 and 29, of steel protected from rust by being incased within the clay blocks filled with concrete or concrete alone. When the wall has been completed to the height at which it is dseired to commence the door, two half blocks are laid upon the wall across the doorway. These should be placed out far enough so that the door may be set down inside. The shoulder or ledge thus formed should be 1¾ inches wide. Through this crosstie and extending to the hollow space of the block on either side of the doorway should extend reinforcing steel. The quantity and quality of this steel will be discussed under the head of door reinforcement. It is necessary here to use ½ block for a crosstie because the form rests upon this and, in the subsequent doorways, it is necessary that the door form should be of sufficient height that the center of each crosstie will be on a level with the mortar joint of the wall, therefore, the top of the bottom crosstie must come on a level with the center of a course of blocks.

Upon this bottom crosstie must be placed the outer one-half of the continuous door form. Then the vertical reinforcement may be hooked to the lower crostie and secured in a vertical position by tying it to the form. Then the horizontal reinforcement of the wall may be hooked to or placed inside of the vertical reinforcement. When the wall is completed to the top of this form the inner portion of the form may be bolted to the outer. The form, crosstie, and wall into which the steel projects, should then be filled for reasons previously given, with moderately wet concrete made up of reasonably fine gravel. The second form may be secured to the first by means of 2x6's. The use of the second form is similar to the first. It will thus be seen that the door frame consists of interlocking steel, thoroughly set in cement which locks it, protects it from rust, and secures it in an air tight manner to the hollow blocks of the wall by running into them a short distance.

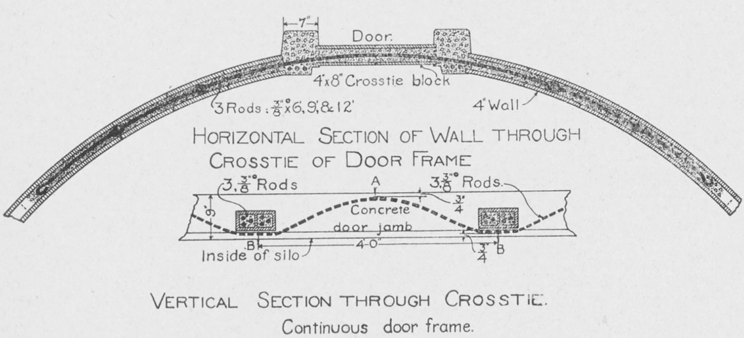


Fig. 29. Section of wall and Crosstie Continuous Door Frame.

FORMS FOR CONTINUOUS DOORS.

A detailed drawing of these forms, two of which are required, is shown in Figure 30. The upper left hand view shows the elevation. The upper right hand view shows the form as seen from the side while the lower or plan view represents the form as seen from above.

One method of procedure in the construction of a set of these forms is as follows: Each part will be designated by letters and dimensions shown on the drawing. All surfaces coming in contact with the cement should be dressed. First two members, lettered "A," may be cut and boards lettered "B" nailed to them 23 inches apart. Pieces lettered "C" may be made from a 2x6. The edge nailed to "B" should be beveled so that the piece will be flared outward in order that it may be easily

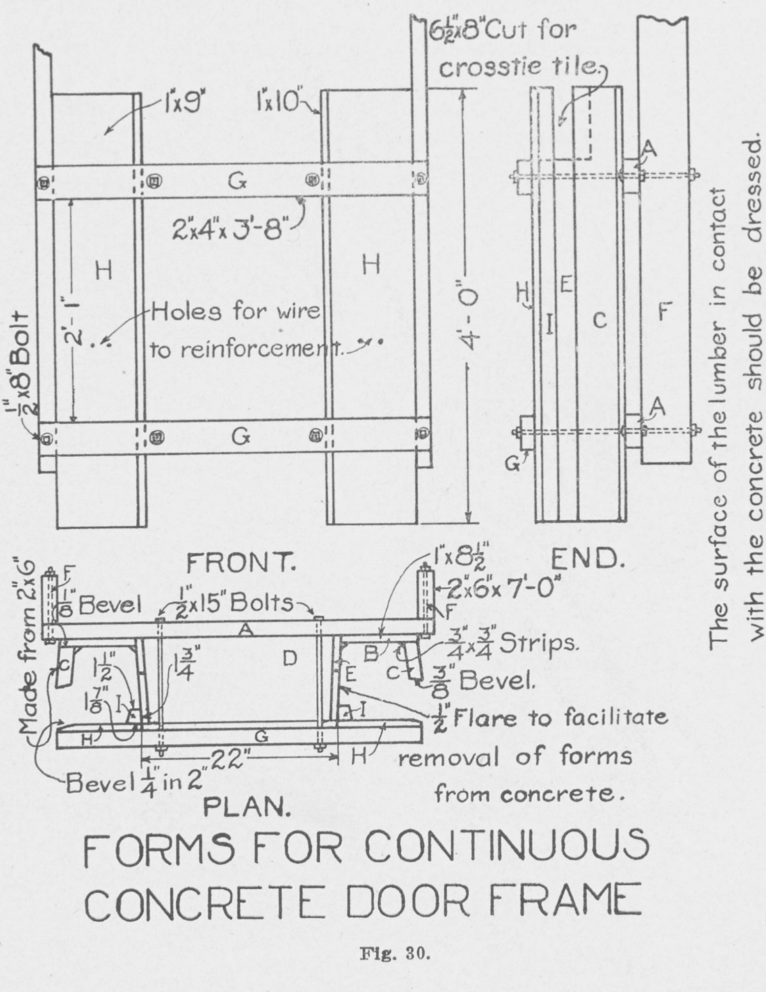
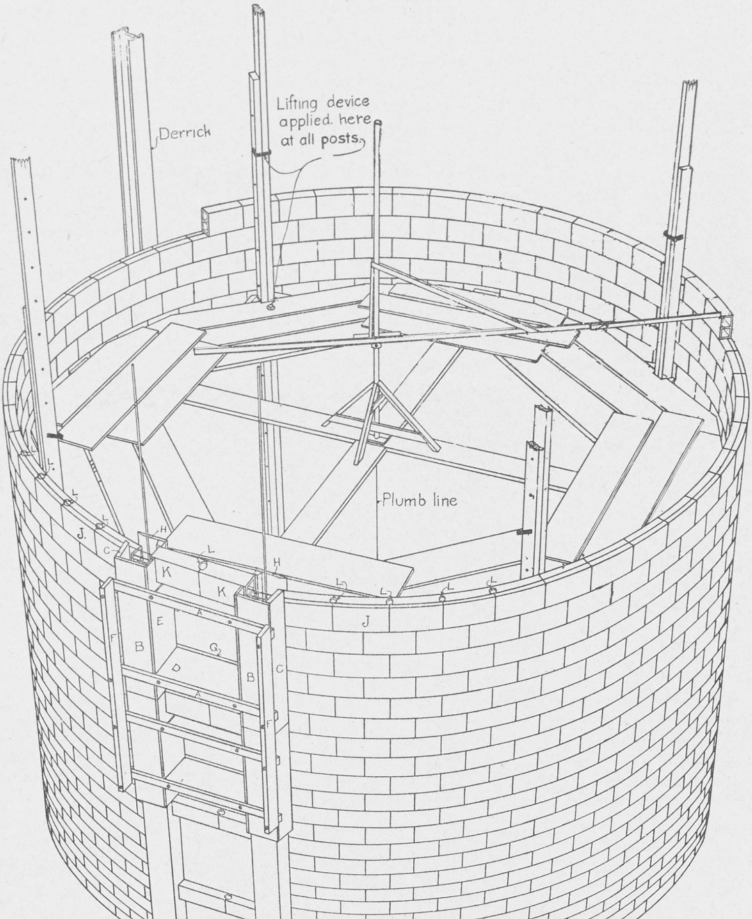


Fig. 30.

removed from the concrete. The other edge of this member should be beveled about ⅜ inch in order to have it fit the circular wall against which it must be clamped.

Two pieces "D" are required and are cut from a 1-inch board. The corner of the piece where "A" and "E" join should be less than a right angle in order that each of the boards "E" may be flared ½ inch toward



SCAFFOLD, GUIDE AND FORMS FOR CONTINUOUS DOOR

Fig. 31.

each other. This is also for the convenience of removing the form from the concrete. The member "E" should be nailed throughout its full length to the edge of "B." Then the piece "D" may be toe-nailed to "A" and the loose edge of "E" nailed back to "D" as seen in drawing Figure 30. In order that the crosstie blocks may be set into each side of the form, it is necessary to saw a notch in "E."

The length of these forms and the location of the notch cannot be determined accurately until the wall is built up to the top of the first form. Then the top of the form should be sawed so that it will be flush with the top of the crosstie when the center of the crosstie is level with the wall mortar joint. The notch will then be of a depth equal to the width of the block and wide enough to permit the crosstie block to rest loosely between the outer and inner form. The necessity of this will be readily seen in Figure 31. The inside corners formed by "B," "C," and "E" should be filled with a three-cornered strip which causes the concrete door frame to be chamfered, leaving smoother work.

In the 2x6's, lettered "F," holes should be bored and ½-inch bolts used. Holes should also be bored in the ends of members "A." These holes should always be bored somewhat larger than the bolt because the forms cannot be held exactly in place and the 2x6 may warp somewhat. Holes should also be bored in "A" for the long bolt extending through the inner portion of the form. This completes the outer portion of the form.

The inner portion of the form is built as follows: Members lettered "G" are cut and to them are nailed the 1-inch boards lettered "H" which are placed 22 inches apart. The boards "H" should be beveled on the edge ¼ inch in two inches to conform to the curvature of the inner side of the silo wall. The edge need not be beveled thinner than ½ inch. The beveled strips lettered "I" are nailed to the end flush with the inner edge of "H." Only a bevel of ⅜ inch is necessary here as the lumber of the door extends across horizontally, therefore there is little or no shrinking or swelling of the lumber in this direction. Holes must be bored in "G" to receive the bolts which hold the two parts of the form together. The cost of these forms need not exceed twelve dollars.

REINFORCEMENTS FOR CONTINUOUS DOOR FRAMES.

If the door frame is made of the dimensions shown in Figure 29, and the vertical jams of the dimensions shown in Figure 30, the amount of steel in each door jam need not have a cross sectional area of more than ¼ square inch, that is, the square reinforcing bar, ½ inch by ½ inch as shown in Plate I will be sufficient. In some cases, it has been convenient to use three ⅜-inch round rods as seen in Figures 32 and 33. This is slightly in excess of the quantity just mentioned but it will be found sufficient to use any kind of steel equivalent in quantity to one ½ inch by ½ inch bar, providing it is bent as shown in Figure 29. This should be bent inside of the steel of the crossties, as seen at "B," and out near the outer surface of the beam at a point "A" midway between the crossties. These rods are easily secured to place by a light wire extended through small holes in form. The reason for thus bending the steel is as follows:

If no steel were used, the pressure of the silage against the door and wall adjacent to the door would probably cause the door jamb to burst outward. In so doing, horizontal cracks or fissures would occur across the outer side of the jamb at "A" and inner side of the jamb at "B" on account of the outward pressure being provided for by the crosstie at "B." The tendency toward the occurrence of such cracks is prevented by steel rods. In order that such rods may act advantageously, they must be near the surface which tends to open. From this it will be seen that the steel rods must be so shaped that they will not slip in the concrete. If the steel used is not a regular reinforcing steel such as the corrugated or twisted bar, it should be hooked in the concrete at the ends.

In placing the steel of the horizontal crossties, it is very important that they shall be attached to each side of the wall very securely. The total amount of steel for the top and bottom part of the crossties should be at least equivalent to 50 per cent more than that found in the wall between the crossties. The longest one of these rods in each section of the crosstie blocks should be 10 or 11 feet, while the shorter one may be 6 to 8 ft., thus a standard piece of 18-foot reinforcement may be conveniently cut into 7 and 11-foot pieces. The upper part of

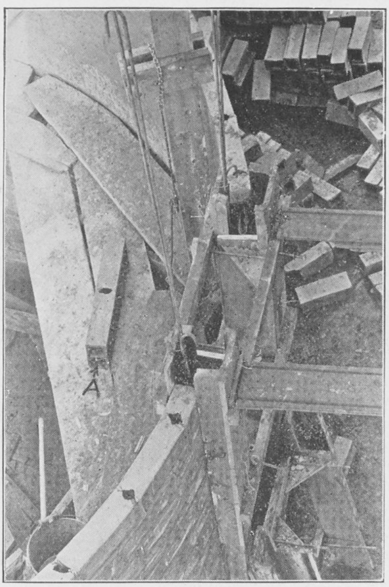


Fig. 32. Looking down upon forms for Continuous Door Frame and Steel in place Ready to Fill with Concrete.

drawing Figure 29 shows a view looking directly through the crosstie laying bare the steel of the crosstie. This is shown as three ⅜-inch rods having hooks at each end. The shortest of these rods is 6 feet long, the medium length is 9 feet and the longest length is 12 feet. A set of these is placed in each of the two openings of the crosstie blocks. Each set extends into separate courses of blocks in the wall. These blocks of both the crosstie and the wall are broken at the top so as to permit their being filled with wet concrete. This causes the crosstie steel to secure a perfectly firm hold upon the wall. If the crosstie steel is also extended from one set of vertical reinforcing to the other there might be some question concerning the strength of the bond of the wall to the door frame. However, this steel extends into the wall so far that the shearing strength of the mortar thus brought under shearing stress is equal to fully as much or more than the tensile strength of the steel itself, therefore the only thing that could happen would be for the crosstie steel to break. This is entirely out of the question as the amount of steel in the crosstie is at least 50 per cent more than that contained in the wall between the crossties. In building up to the top of the door form, it will be found convenient to have only the outer portion of the form in place. Than the steel of the lower part of the crosstie may be bent approximately to the circle of the wall and pushed around in the course of blocks, lettered "J," shown in Figure 31. Plain, straight crosstie blocks should then be placed in pairs as shown at "K," Figure 31. Twenty-five of these blocks should be ordered for the entire silo, allowing for breakage. These may be conveniently held end to end by passing a light wire through one opening of each block, back through the other, and twisted together tightly. This stage of progress is shown at Figure 33 at "A."

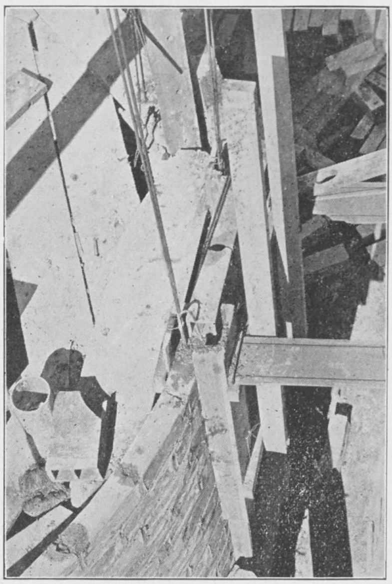


Fig. 33. The Forms of Figure 32 Filled with Concrete.

After the blocks are placed, the steel within the courses "J" may be pushed through the bottom opening in "K" into the wall on the other side of the door, until each piece of steel is extended an equal distance into the wall on each side of the door. This course "J" may then be conveniently filled with concrete through the holes "L" which should be broken in the block before they are laid. The breaking of these holes is easily accomplished by striking from the inner part of the block outward.

The reinforcement from the mortar joint above "J" should be extended into "K" far enough so that the hooked ends will pass. This will necessitate cutting some of the reinforcing wire the same length as was used in the foundation. The next course of blocks above "J" can then be laid. It will be necessary to break holes in these blocks as before. In addition to this, the end of the block partition or web must be broken out in order that the concrete may be placed in the lower part of this course of blocks. The steel may then be pushed around in this course and drawn back through the crosstie blocks as was described for the steel in the lower portion of the crosstie. Concrete should then be poured in around this steel, filling that portion of the blocks into which the steel extends.

In Figure 5 is shown a view of the outside of the continuous door frame looking up. On either side of the door frame may be seen bolts projecting from the mortar joints to which a 2x4 was subsequently bolted in order that the chute might be attached. A detail of these bolts is shown in Figure 34. It is to be noted that cross-

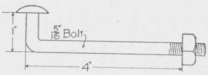


Fig. 34. Bolts.

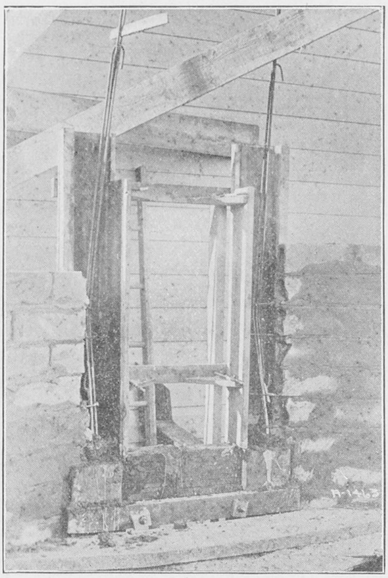


Fig. 35. Vertical Reinforcement of Round Rods in place. Inner Half of Forms To Be Put in Place. Note Ends of Reinforcing Wires Extending from Mortar Joints.

ties are out far enough to clear the doors which rest in the shoulders at each side of the doorway. In Figure 35 may be seen the vertical reinforcement of the door-jambs and the horizontal reinforcement of the wall. The photograph from which this figure was made, was taken from the inside of a silo being built of 4x5x12 inch blocks, when the silo was about one-half completed, which explains the absence of steel from two of the mortar joints.

CONSTRUCTION OF DOORS.

The doors to fit the individual doorway must be curved and may be made as shown in the drawing Fig. 36. Two cleats may be sawed to the proper curve and two thicknesses of 6 inch fence flooring nailed to the inner side of the curve, between which should be placed a layer of tar paper. The cleats should not reach closer than within $1\frac{1}{2}$ inches of side of the door, as a $1\frac{1}{2}$ inch bearing will be necessary between the door and the concrete door frame.

Two principal kinds of doors have been successfully used in the continuous doorway. Fig. 44 shows a door made of two thicknesses of fence flooring crossed with tar paper between. These doors are beveled at the end to set loosely into the beveled shoulder in the concrete.

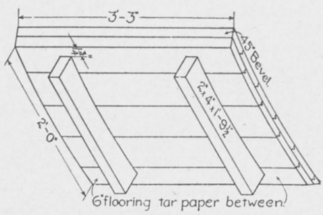


Fig. 36. The Individual Type of Door.

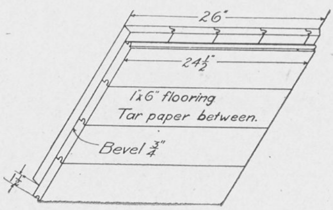


Fig. 37. The Type of Continuous Door.

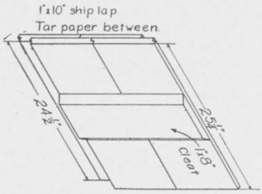


Fig. 38. A Cheaper Type of Continuous Door.

A cheaper and very good door is shown in Fig. 38. This door as shown is made of two thicknesses of shiplap, that lap onto each other about 2 inches and are not beveled at the ends. The boards on the outer side are shorter than those on the inside. A wide cleat with beveled edges is nailed to the inner side of the door and on the different doors meet end to end, thus offering little obstruction to the free settling of the silage.

In order that any silo may fulfill its purpose, it is necessary that the joints between the doors and the door frames be air tight. It seemed difficult to obtain air tight joints between wooden doors and masonry door jambs, therefore, in silo No. 1 different methods of sealing the doors were tried. A few of these methods admitted air to the silage, thus causing the loss of as much as four or five cubic feet of silage at one door. Sealing with clay was found to be satisfactory where reasonable care was exercised in its use. This becomes a very simple matter by taking a quantity of fine clay, wetting it until sticky but quite stiff, and filling the shoulder of the door frame with this before pressing the door into place. If the mud is rather stiff it will hold the door to place until the silage is up high enough to secure it permanently. The moisture of the silage keeps the clay damp on the inside thus making it air tight. This is one of the oldest and best methods of sealing doors. It has been thoroughly tried and found to be very satisfactory.

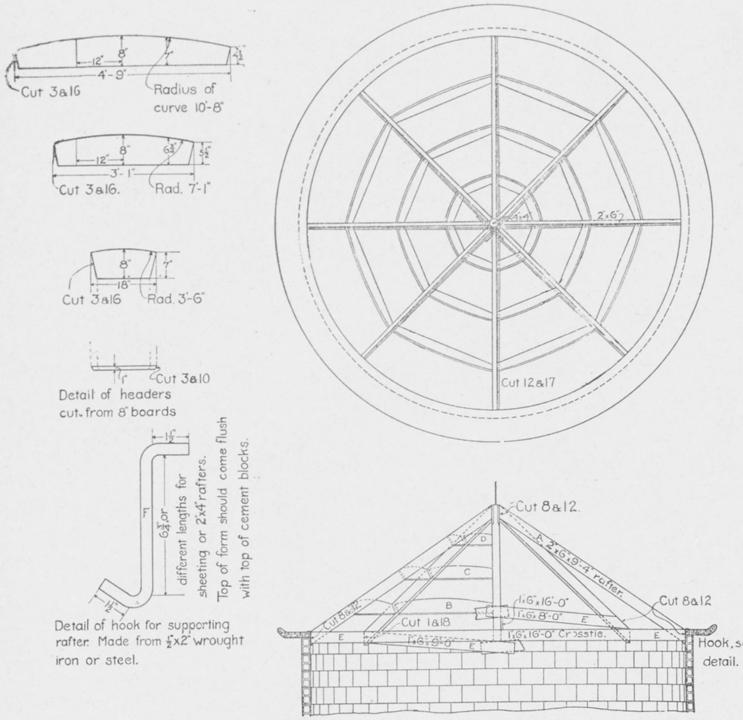
THE ROOF.

Perhaps the greatest advantage of a roof is the lessened liability of the silage freezing. Not only is it impossible to prevent freezing in severe weather unless the silo is provided with a roof, but during snowy or rainy weather the silage is mixed with snow or wet down with rain. Furthermore, a silo without a roof becomes a catching place for husks, dust or anything carried in the wind and a favorite feeding ground for the neighborhood pigeons and birds. Although many silos are not provided with roofs and the live stock eagerly eat the silage from them, it is evident that a roof would not only reduce the amount of frozen silage, actually save silage and preserve its quality, but be worth its cost in making a more pleasant place to feed from in bad weather. The roof is also valuable in adding to the silo's appearance. A door for filling, large enough to admit the carrier or elevator from the ensilage cutter, should be placed in the roof. Some light should be admitted to the silo for if not it will be necessary to use a lantern when removing the silage. It is advisable to have all portions of a building as near equally durable as possible, therefore, concrete roofs have been built on several, and a convenient method of construction has been developed for the same. In case a wooden roof or any other kind of a roof is desired, a plate made up of two thicknesses of 1-inch lumber sawed to the proper curvature may be bolted down to the upper course of blocks.

One of the first considerations is the pitch of the roof. The first Iowa silo built was covered with a 1/4 pitch roof. This gave only four feet of head room under the roof at the center for a man to work when finishing the filling of the silo. Roofs put on with a 1-3 pitch seem considerably more satisfactory both in outward appearance and in the amount of head room secured beneath. In building 1/2 pitch concrete roofs it has been found quite difficult to place the concrete on the forms. The forms being so steep that if the concrete is made as wet as is desirable, it will slide down the form, therefore, the following discussion will pertain entirely to 1-3 pitch roofs.

Figure 39 and Figure 40 give a general idea of the false work for roof. Both ends of the eight rafters lettered "A," will be cut plumb. The rafters may be made of 2x4's or 2x6's, depending somewhat on the size of the silo. Sound 2x4's have been used successfully on 16 foot silos.

Three headers lettered "B," "C," and "D," are placed at approximately equal intervals measured at the center point of the headers. The headers may be made of sound 1x6's or 1x8's. It will generally be better to use 1x8's for the lower header "B." These headers are shown in detail for a 16 foot silo, and would serve for a larger silo provided an extra header would be placed below "B," and the plan as shown will serve for a smaller silo. In this case header "B" will simply come closer to the lower end of the rafter. A center piece to which the rafters must be nailed is conveniently made from two 2x4's chamferred at the upper end, thus giving a bearing for the eight rafters. It may be found convenient to use a small round post instead of the 2x4's. The weight of the concrete upon these rafters would press outward upon the wall which is generally green when the roof is built, therefore, it is necessary to securely tie the lower ends of the rafters together with 1x6 pieces, "E," in order to prevent their spreading. This prevents any outward thrust on the wall.



FALSEWORK FOR CONCRETE ROOF

Fig. 39.

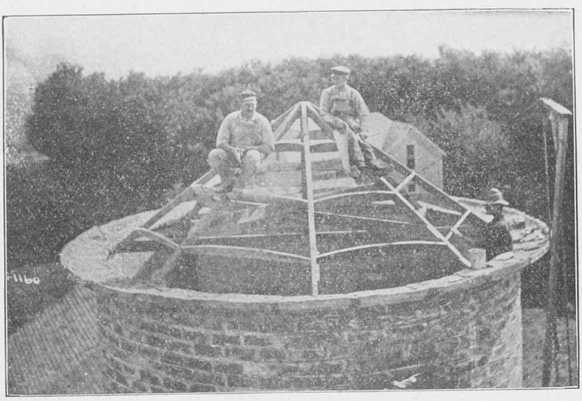


Fig. 40. False Work and Cornice Block in Place Ready to Receive Sheeting

Three successful methods of supporting this false work have been used. The lower end of the rafters may be supported in a stirrup or hook made up of ½"x2" iron or steel as shown at "F." They have also been supported by a studding reaching up from the scaffold. A third and very successful method consists of laying a couple of blocks flatwise instead of on edge directly under each rafter. This is shown in Figure 41. A short stud resting upon the blocks and reaching up to the rafters will support it nicely. If this projection inside proves objectionable, it can afterwards be chiseled off very easily without any danger of injuring the wall.

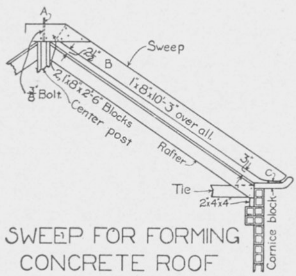


Fig. 41. Sweep for Forming Concrete Roof.

Two kinds of covering for this false work to hold the concrete have been used. The first is expanded metal. The kind best adapted for this and the only kind which has been used is "Hy-Rib." This is cut and wired together over the rafters and of course serves as a permanent reinforcement for the roof. As will be seen in the next paragraph, a much smaller amount of reinforcement is sufficient. This operation is shown in Figure 42.

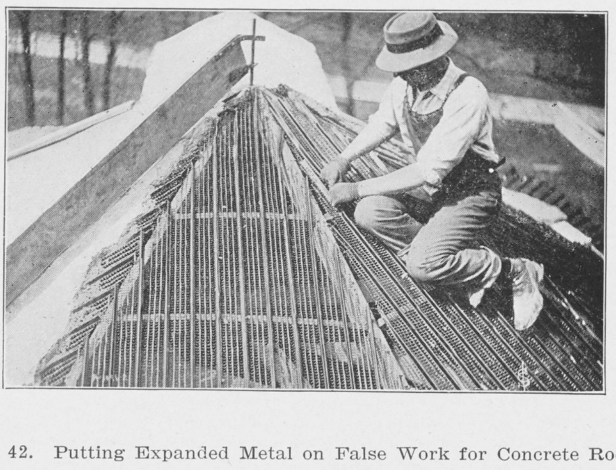


Fig. 42. Putting Expanded Metal on False Work for Concrete Roof.

The second method consists of securing boards the length of the rafters and ripping the same diagonally from corner to corner. These may be placed upon, and very lightly nailed to the frame work. The necessary amount of expanded metal rigid enough to support the concrete while resting on the headers for a 16 1-3' pitch roof will cost between $15 and $20. The necessary sheeting costs approximately three-fourths as much. It costs a trifle more to rip and place the lumber than to cut and place the expanded metal but still the lumber when placed on roof is cheaper than the metal. The use of the lumber has at least two additional advantages in that it may be removed after a few days and used again for another silo or roof sheeting on any building being built, also the roof need not be plastered beneath.

The weight of the roof causes an outward pressure tending to spread the lower portion of the cone and cornice. In order to prevent any such action as this, it is necessary to place steel in the concrete around the base of the roof directly over the wall. The quantity of steel necessary for a 16-foot roof is one ½x½-inch square rod or its equivalent, extending continuously or with ends hooked together around the roof. This steel like any other reinforcement should be thoroughly covered with concrete in order to prevent rusting. Any scraps of ¼-inch wire or other light steel available may profitably be laid in the wall extending from over the cornice blocks up toward the center of the roof.

The thickness of the roofs already built is about 3 inches at the lower edge and gradually reduced to about 2½ inches at the peak. With good clean, coarse sand and medium coarse gravel, a mixture of 1 to 3½ will be found about right for the roof. Further experiment may prove that a less thickness of concrete is required if woven reinforcing or fencing is used. A thin coat of richer mortar is troweled on the top of the roof will serve nicely as a finish or an even cheaper and a very good method is to simply paint the roof with a cement wash before it has time to completely set. In either case a good coat of plaster should be placed on the cornice blocks when used. In spreading this concrete over the form it is very advantageous to have an accurate guide for the purpose. In the top of the center piece of the form to which the rafters are nailed may be placed a ½-inch bolt or rod lettered "A," as seen in Figure 41. A 6-inch or 8-inch board lettered "B" may be secured by means of two pieces of board as seen in the same figure or by means of a strap iron, shown in Figure 42, to the rod "A." The lower end should be rounded off to the proper shape for the gutter. When the lower end is blocked upon a ¾-inch piece, the board should extend three inches from the upper surface of the form at the lower end of rafters, and 2½ inches from the upper. Then the concrete may be placed upon the form and struck to the proper shape by swinging the board "B," resting upon the block lettered "C." By this means a well shaped roof of uniform strength may be secured. This operation may be seen in Figure 42.

The opening in the roof for admission of silage while filling may be either a dormer window or a trap window. The false work for the former is shown in Figure 43. It smply consists of a light frame work placed on the regular roof form. To this frame work may be wired expanded metal, sides and window jambs, also the same material will serve for a skeleton for the roof. When this is placed, it is only necessary to plaster with a good thick coat of plaster, after which the frame work within should be removed and the inside plastered. A barn sash of proper size, approximately 20x24 inches may be hung by means of "T' hinges to the concrete. The strap end of the "T" hinge should be secured to the expanded metal before plastering on the inside. Then the window is beveled all around and blocked to place. The plaster inside may be filled flush with the sash and a good tight joint thus secured.

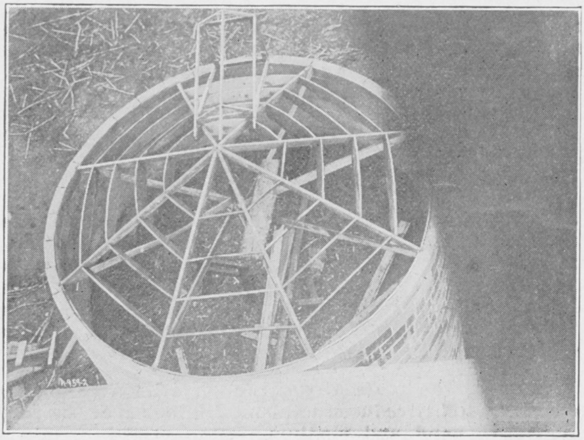


Fig. 43. False Work for Roof with Dormer Window.

A trap window is considerably cheaper and fully as serviceable as the dormer. It may be constructed as follows: Referring to drawing Figure 44, a tapered form made of 2x6's may be placed directly on the top of the form of the roof. On the upper side at "B" is seen a crown strip of 1-inch lumber lapping down 1⅜ inches upon the outside

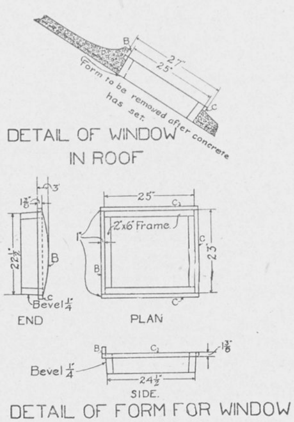


Fig. 44.

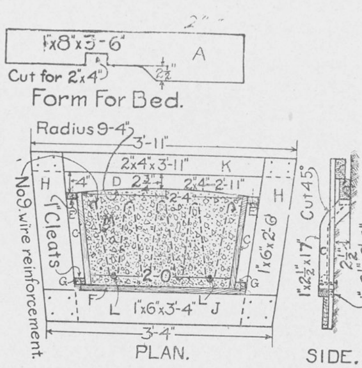
of the main part of the frame. This extends up at the highest point three inches. On the other three sides are simply ¾-inch by 1⅜-inch strips "C" nailed outside of the end, flush with the top of the frame. On all except the lower sides of the frame the concrete is thickened to the top of the form giving a thick edge as seen near "B," Figure 44. This causes all rain not falling directly upon the sash to flow away. The concrete on the lower side is simply built up to the under side of the cleat, thus, the rain falling on the sash will simply

flow ofl the sash onto the concrete below and cannot become pocketed in any crevice. It will be seen that there is a shoulder extending around this window opening into which a standard barn sash may be placed. On each side of this sash, hook eyes or heavy wire staples should be secured in the concrete in such a way that the window may be hooked to them. A wire screen should be tacked on the sash to protect the glass from hail.

If the weather is warm, favorable to rapid setting of cement, and a fairly quick setting cement is used, the false work under the roof need not be left more than two or three days after the roof is completed. In case one scaffold, etc., is desired in building successive silos, the scaffold and form will ordinarily be ready to remove from the completed job by the time the next silo has progressed sufficiently to need the scaffold.

CORNICE BLOCKS.

In Figure 40 is seen the cornice blocks placed ready for the adding of the concrete of the roof. This cornice projects 12 inches beyond the wall, and forms a gutter of a very desirable width.



CORNICE BLOCK FORM

Fig. 45. Cornice Block Form.

As seen from the Figure 45, the block is 2½ inches thick, 2 ft. long, and 17 inches wide. No. 9 reinforcing wire, as indicated by the broken line "M," is placed in the block. These wires may be conveniently bent to shape by placing in a row four headless spikes at a distance of about 14 inches from a similar row of five spikes. To the end spike of one of the rows may be secured one end of the wire which is then woven from row to row around alternating spikes. Near the inner corners of the block and in the loops of the reinforcement are bent spikes as shown at "L," Figure 45. In making the blocks, these spikes are placed with their heads in the ground about one-half inch so that when these blocks are set on the wall, the spike heads will project out from the top for tying the blocks down to the wall as shown in Figure 46.

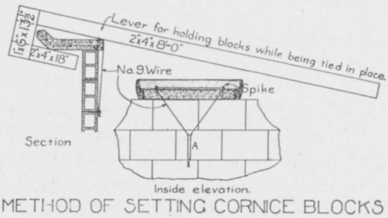


Fig. 46. Method of Setting Cornice Blocks.

The method of making these blocks is shown in Figure 47. It may be seen that the blocks are made upside down on the ground. The man in the background is forming a proper shaped bed upon which to make the blocks. The ground under the lower end of his forming board, lettered "A," is spaded and formed by sliding it along the guide "B." The form is assembled upon this bed and filled one-half full of concrete, then the reinforcing wire and the spikes already referred to should be placed, then the filling of the form completed.

It will be seen that the outer end of the block is curved and the bevel of the block may be easily made curved by cutting the edge of a board similar to the curved part of the form. Then as this board is held horizontally against the side pieces of the form and drawn toward the operator as shown in Figure 47, the proper curvature will be given to the beveled portion of the block. Then the surface of the block may be troweled smooth and it will usually be found best to cut completely around the block with a brick trowel or another thin tool. As soon as this is done, the outer frame of the form may be removed and the form taken away and placed ready for the next block. Three men should make enough blocks for a 16 or 18 foot silo in a half day.

The mixture for these blocks should be quite rich for there is liable to be considerable strain upon them while the roof is being built. Good clean sand and mediumly coarse gravel, and a mixture of three to one will be found to give good satisfaction. About twenty-four hours after making these blocks, they should be turned over and scraped clean of dirt on the under side. Then the blocks may be one another as they are very liable to break while so green. In ricked up edgewise on the ground but never should be piled upon ricking them up they are gotten out of the way and placed in a convenient form to sprinkle. It must of course, at all times, be borne in mind that any concrete work should be kept wet for several days after making.

FORM FOR CONCRETE CORNICE BLOCK.

In Figure 45, the form and forming board for bed may be seen. The dimension of the block should be approximately 2 feet at the shortest side, thus permitting it to bond properly with the clay blocks of the wall. The entire width of the block as seen in the drawing is 17 inches. This gives a projection of at least 12 inches. The dimension of the outer side of the block is 2 feet 4 inches which makes the ends of the block radial so they will fit together when placed. This dimension in other than 16-foot silos will be slightly different.

The forming board, lettered "A" is on the lower edge shaped the same as the concave surface of the block. The location of the notch is immaterial and would be made to fit any straight piece of lumber which is convenient to use as a guide.

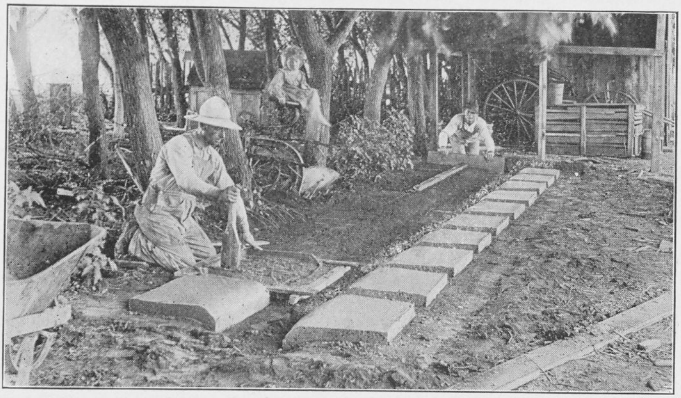


Fig. 47. Making Cornice Blocks.

The form itself is made up of two end pieces, "C," 1 inch thick, whose proper dimensions are shown in the side view. The curved edge of the block is formed by the member "D" which is made from a 2x4 by hewing one edge to the proper curvature. This curvature is easily determined in any case, and in this form the radius is 9 ft. 4 inches. At the end of "D" should be placed cleats, "E," to hold the end pieces to place. The inner edge of the block is made straight and that portion of the form simply consists of a board, lettered "F," 1 inch thick, 2½ inches wide, and approximately 30 inches long. The length of "D" and "F" simply needs to be sufficient to permit the nailing on of the cleats lettered "G" which hold the pieces "C" to place. Then the outer frame is made up of three pieces, of 1x6, "H," "H," and "J," and the 2x4, "K,' as shown in the plan, which is nailed beneath the boards, "H," while the board "J" is nailed on the top. The importance of this will be seen in the side view. It will be readily seen that this outer frame is merely to hold the form in the proper shape.

In Figure 40 is shown the cornice blocks set on the wall. It will be readily seen that on account of the blocks projecting so far over the wall it will be necessary to tie the inner portion of the block down to the wall. The method of doing this is shown in Figure 46. The first consideration is the method of holding the block to place while it is being tied. The most convenient method consists of the use of the lever which is hooked under the outer portion of the block while it is still resting on the scaffold. Two men may take the block by the inner corner and lift it to place while the outer end of the block is supported by the end of the lever provided, while the inner end is tied down. The method of tying the block down is shown by the inside elevation of the wall. A spike should be placed in one of the mortar joints of the wall while the mortar is still green, then a number 9 wire is looped over the two nail heads in the block and the spike in the mortar joint forming a triangle. The tightening of the wire may be accomplished by looping a piece of light wire about both ends of the tie wires above the lower spike. The outer end of the block may be held above its final position while the loop is being slipped up, and by letting the outer end of the block down carefully it will be readily seen whether the wire is tightened sufficiently or not. The blocks are, of course, well set in cement mortar and, after the roof has had an opportunity to harden, these tie wires may all be removed.

ORDER OF CONSTRUCTION.

In any construction it is necessary to perform the different parts of the work in a certain order or delays are sure to occur. The following is given with the idea of helping to eliminate delays from such causes.

It is necessary to make the cornice blocks, door forms, scaffold, derrick, and guide before the silo wall is started. In case one set of forms is utilized to build more than one silo, it will be found advantageous on the second silo to make the cornice blocks, complete the excavation, construct the foundation, and the wall to scaffold height, and sometimes the floor before the scaffold and false work are removed from the first. The putting in of the floor will depend largely upon the weather. If for any reason it is inconvenient to put in the floor, at this time, it may be put in after the silo is complete and the scaffold, etc., removed. This will give the concrete roof sufficient time to set properly.

After the silo wall is completed, the next work will be to place the roof false work which should be previously framed. This framing cannot usually be done until the diameter of the silo is accurately determined by constructing a part. However, any slight variation in the size of the silo in which any such frame work may be afterwards used, may be allowed for by varying the size of the center post of the false work. Any one of the three methods shown in Figs. 39 and 41 for supporting the false work may be used with safety. The position of this false work should be such that the bottom of the main part of the roof will be flush with the top of the cornice blocks. In placing the concrete upon the false work, it will be found convenient to stand upon a cleated plank which lays upon the false work and rests at the bottom upon the cornice blocks.

It is highly desirable to commence placing the concrete sometime in the forenoon in order that it may be all placed the same day. If possible, it will be more convenient to commence placing the concrete at a point opposite the derrick and extend the work to the peak as the work progresses around the roof. Care should be exercised to eliminate any unnecessary jarring of the roof after any considerable portion of the concrete has been placed. Any such jarring tends to form minute checks about the rafters.

A BILL OF MATERIALS OF AN IOWA SILO

The following is a bill of materials for an Iowa silo 16 feet in diameter and 35 feet high, with concrete roof, as shown in Plate I. This bill may be easily modified for other sizes. The different types of foundations, doors, etc., are included, from which choice may be made to suit condition.

Type one foundation:		
Blocks 4x8x12		130
Cement		1½ sacks
Lime		1½ sacks
Sand		2-9 yd.
Type two foundation:		
Cement		2½ bbls.
Gravel		2 yds.
Type three foundation:		
Cement		5¾ bbls.
Gravel		4½ yds.
Type four foundation:		
Cement		6½ bbls.
Gravel		5 yds.
Material for forms:		
Stakes, 24 pcs. 2"x4"x 6'	98 bd. ft.	
24 pcs. 2"x4"x 2'	32 bd. ft.	290 bd. ft.
Braces, 24 pcs. 2"x4"x10'	160 bd. ft.	300 bd. ft.
Sheeting, ½-inch lumber		
Floor:		
Cement		2 yds.
Gravel		2½ bbls.

Wall:

Blocks, 4x8x12		3000 *
Freight on 18 to 24 tons		
Cement		5 bbls.
Lime		5 bbls.
Sand		2 yds.
Steel No. 3 wire, hard		400 lbs.
18 pcs. ½"x½"x18' reinforcing bars		276 lbs.
No. 12 soft wire		5 lbs.

*In case type four foundation is used, the number of blocks will be about 150 to 200 less.

Scaffold:

Posts, 20 pcs. 2"x6"x16'		320 bd. ft.
Frame work, 5 pcs. 2"x8"x12'		80 bd. ft.
Plank below scaffold 2 pcs. 2"x8"x16'		44 bd. ft.
Platform 2 pcs. 2"x12"x14'	56 bd. ft.	
2 pcs. 2"x10"x16'	54 bd. ft.	
6 pcs. 2"x12"x16'	192 bd. ft.	746 bd. ft.
4 pcs. 1"x12"x16'		64 bd. ft.

Braces for holding post before wall is started:

8 pcs. 1"x6"x16'		64 bd. ft.
4 wire stretchers		
4 clevises		

Forms:

Individual Door Form:

Lumber, 2 pcs. 2"x 6"x10'	20 bd. ft.	
1 pcs. 2"x 6"x16'	16 bd. ft.	
1 pcs. 2"x 4"x14'		
2 pcs. 2"x 4"x12'	25 bd. ft.	61 bd. ft.
4 pcs. 1"x10"x14'		
1 pcs. 1"x10"x14'		
2 pcs. 1"x10"x16'	88 bd. ft.	88 bd. ft.
Eight ½"x10" machine bolts		
Eight ½"x17" machine bolts		

Continuous Door Forms:

Lumber, 1 pcs. 2"x 4"x 8'		
2 pcs 2"x 4"x14'	24 bd. ft.	
2 pcs. 2"x 6"x16'	32 bd. ft.	56 bd. ft.
4 pcs. 1"x10"x14'	47 bd. ft.	
1 pcs. 1"x10"x 8'	7 bd. ft.	54 bd. ft.
Eight ½"x 7" machine bolts		
Eight ½"x15" machine bolts		

Guide:

¾"x1½"x14' stop		
2 pcs. 4' lath		
2"x4"x8'		5 1-3 ft.
8' gas pipe 3" or 1"		

Derrick:

3 pcs. 2"x6"x16'	48 bd. ft.	
1 pcs. 2"x6"x 6'	6 bd. ft.	48 bd. ft.
6 pcs. 1"x6"x16'	48 bd. ft.	20 lbs.
3 guy wires (100 ft. each) No. 9 wire		54 bd. ft.

Individual Doors of Figure 43 (six are required):

Fence flooring	96 bd. ft.
2x4 cleats	16 bd. ft.
Tar paper or prepared roofing	6 sq. yds.
8d nails	

Continuous Doors of Figure 44:

Fence flooring	152 bd. ft.
Tar paper or prepared roofing	10 sq. yds.
6d nails	

Continuous Doors of Figure 45:

10 inch shiplap	172 bd. ft.
Tar paper or prepared roofing	10 sq. yds.
6d nails	

Roof:

Cornice Blocks:

Cement	1½ bbls.
Sand	¾ cu. yd.
Steel No. 9 wire	10 lbs.

Form for Cornice Blocks:

1 pcs. 1"x8"x3½'	
1 pcs. 1"x6"x12'	8¼ bd. ft.
1 pcs. 2"x4"x7'	5 bd. ft.

Lever for Setting:

1 pcs. 2"x4"x8'	5 2-3 ft.
Cement	5 bbls.
Gravel	2 yds.
Steel 3 pcs. ½"x½"x13'	46 lbs.

False Work:

26 pcs. 1"x12"x10' sheeting	
8 pcs. 2"x 6"x10' rafters	260 bd. ft.
1 pcs. 4"x 4"x 6' or 1 cedar post	88 bd. ft.
5 pcs. 1"x 8"x16'	
4 pcs. 1"x 6"x16'	86 bd. ft.
8 forgings shown in Figure 46	

LABOR REQUIRED FOR THE CONSTRUCTION OF AN IOWA SILO

16 FEET DIAMETER AND 35 FEET HIGH WITH CONCRETE ROOF

The following estimate is based upon the use of 4x8x12 curved blocks, and a silo 16 feet diameter and 35 feet high with concrete roof. By modifying this estimate to suit any other size of silo or local labor conditions, a quite definite idea of labor cost may be obtained.

Excavation:

4 men 5 hrs.

1 team 5 hrs.

Footing:

Type One:

Mason 3 hrs.

Mason helper 3 hrs.

Unskilled labor 3 hrs.

[illegible]o:

Mason 4 hrs.

Mason helper 4 hrs.

Unskilled labor 4 hrs.

Type Three:

Mason 6 hrs.

Mason helper 6 hrs.

Unskilled labor 6 hrs.

Type Four:

Labor on concrete and forms.

Mason 15 hrs.

Mason helper 15 hrs.

Two unskilled laborers 15 hrs. each

Floor:

Mason 5 hrs.

Mason helper 5 hrs.

Two unskilled laborers 5 hrs. each

Individual Door Forms:

Carpenter 20 hrs.

Continuous Door Forms:

Carpenter 15 hrs.

Scaffold:

Carpenter 10 hrs.

Unskilled laborer 10 hrs.

Wall:

Mason 60 hrs.

Mason helper 60 hrs.

Two unskilled laborers 60 hrs. each

Doors:

Individual Type:

Carpenter 6 hrs.

Continuous Type, shown in Figure 44:

Carpenter 5 hrs.

Continuous Type, as shown in Figure 45:

Carpenter 3 hrs.

Roof:

Cornice blocks making:

Mason 5 hrs.

Mason helper 5 hrs.

Unskilled laborer 5 hrs.

Cornice block setting:

Mason 6 hrs.

Mason helper 6 hrs.

Two unskilled laborers 6 hrs. each

Framing false work:

Carpenter 6 hrs.

Placing false work:

Mason 3 hrs.

Mason helper 3 hrs.

Two unskilled laborers 4 hrs. each

Placing concrete:

Mason 8 hrs.

Mason helper 8 hrs.

Two unskilled laborers 8 hrs. each

Removal of false work and scaffold:

Three unskilled laborers 6 hrs. each